Naval Surface Warfare Center
Carderock Division
West Bethesda, MD 20817-5700

NSWCCD-TR–1999/14 March 1999

Survivability, Structures, and Materials Directorate

Technical Report

Rechargeable Li/Li_xCoO_2 100 Ah/600 Ah Battery with Integral Smart Charge Control

By Charles J. Kelly
(Alliant Techsystems, Inc., Alliant Power Sources Company)
Patricia H. Smith and Stanley D. James
(Naval Surface Warfare Center)
Charles W. Fleischmann
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The Navy is seeking to develop advanced rechargeable batteries for propulsion of underwater vehicles. Emphasis is placed on achieving high energy density as opposed to cycle life. The goal of this effort was the development of a battery that could deliver twice the energy density (100 Wh/lb) of the zinc/silver oxide system presently employed by the SEAL Delivery Vehicle.

The lithium/lithium cobalt oxide ($Li/Li_{0.5}CoO_2$) electrochemistry was developed at the 100 ampere-hour cell level. This cell served as the unit building block of a series/parallel-connected battery. Charge and discharge control circuitry was added to each individual cell. This made each cell of the battery protected from operator error and unbalanced charging.

Results are reported on the cycling behavior of thirty, 100 ampere-hour cells along with a battery test, for demonstrating smart battery electronics control and monitoring on a six cell battery. Test data on battery response to the control monitoring system is presented along with a complete users manual for its PC based Smart Battery functionality.

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* Kelly, Charles J., *Rechargeable Li_xCoO_2 100/600 Ah Battery with Integral Smart Charge Control*, Alliant Techsystems, Power Sources Center, Horsham, PA, Mar 1999.

1.0 INTRODUCTION

The goal of the current program was to demonstrate performance in cells sized for SEAL Delivery Vehicle (SDV) use. Under the performance contracts, Alliant Techsystems (Alliant) developed a rechargeable $Li/Li_{0.5}CoO_2$ cell that had a minimum 100 ampere-hour (Ah) capacity (See Figure 1), which served as a design precursor to the SDV-sized cell. Initially, the cell size believed to be the best unit multiplier for the SDV was set at 600 Ah. Four, 600 Ah cells were gauged to fill a single SDV tray (a single cavity in the newer SDV Battery Box). Later, it was decided to revise the unit cell to 300 Ah for structural considerations.

This report is divided into seven sections and three appendices. Section 2 describes the technical requirements. Section 3 discusses the design, processes, and unique features of the 100 Ah cell. In Section 4, the electrochemical performance of the 100 Ah cell is characterized to allow consideration of the cell for general applications. Section 5 describes an *in situ* controller and monitor for the battery. Conclusions are provided in Section 6.

1.1 Background

Underwater vehicles have been battery-powered since the late 19th century. Originally, lead-acid batteries were used. At the five to six hour rate, lead-acid batteries can provide up to 2000 cycles depending on the design, but gravimetric energy densities measured only in the teens. The mission range of an underwater vehicle powered by a battery is limited by the battery's energy density at a given power density. Smaller underwater vehicles are preferably powered by silver oxide/zinc (AgO/Zn) batteries, the only other rechargeable system used for these applications. That system was selected because it can provide three times the energy density of lead-acid. No other commercially available battery provides as high an energy per unit weight or volume. Vehicle range is thereby increased, but a severe loss in cycle life must be accepted. Under optimum conditions, AgO/Zn cells provide about 50 cycles at 50 watt hours per pound (Wh/lb). Users in the field have reported far fewer cycles. They have been under active development and production for half a century and have found a niche market when high cycle life and low cost are less important than energy density.

The technical approach has been to develop a battery based on a more energetic couple than AgO/Zn for the SDV and other submersibles. The system selected for development was lithium/lithium cobalt oxide (Li/Li_xCoO_2) which included the following design goals: provide a minimum energy density of 100 Wh/lb over at least fifty cycles, at -2°C to 35°C; and last five years in storage. This work continues earlier research. That work developed and evaluated 7 to 30 Ah prismatic cells[1] and investigated the Li/Li_xCoO_2 system in AA size* cylindrical cells.[2] Finally, the relative advantages and disadvantages of Li/Li_xCoO_2 and AgO/Zn were compared.[3]

Earlier work on the Li/Li_xCoO_2 system demonstrated its unique characteristics: high energy density, high cell voltage, excellent rate capability, and good reversibility. Because of these studies, the baseline was defined. The cell reaction is given by Equation 1-1.

$$\text{(Charged) } (1-x)\,Li + Li_xCoO_2 \leftrightarrow Li_{1.0}CoO_2 \text{ (Discharged)} \qquad (1\text{-}1)$$

* American Standards Association

On discharge, lithium metal is oxidized at the anode to lithium ions, which dissolve in the electrolyte. Correspondingly, lithium ions are reduced at the cathode and inserted (intercalated) into the crystal lattice of Li_xCoO_2. At full discharge, the value of x in Li_xCoO_2 is unity. One Faraday per mole (F/mole) would be transferred if the initial value of x were zero and the final value one (one electron transferred). To achieve consistent capacity over about fifty cycles, however, the range of x must be limited to between 1.0 and about 0.5.

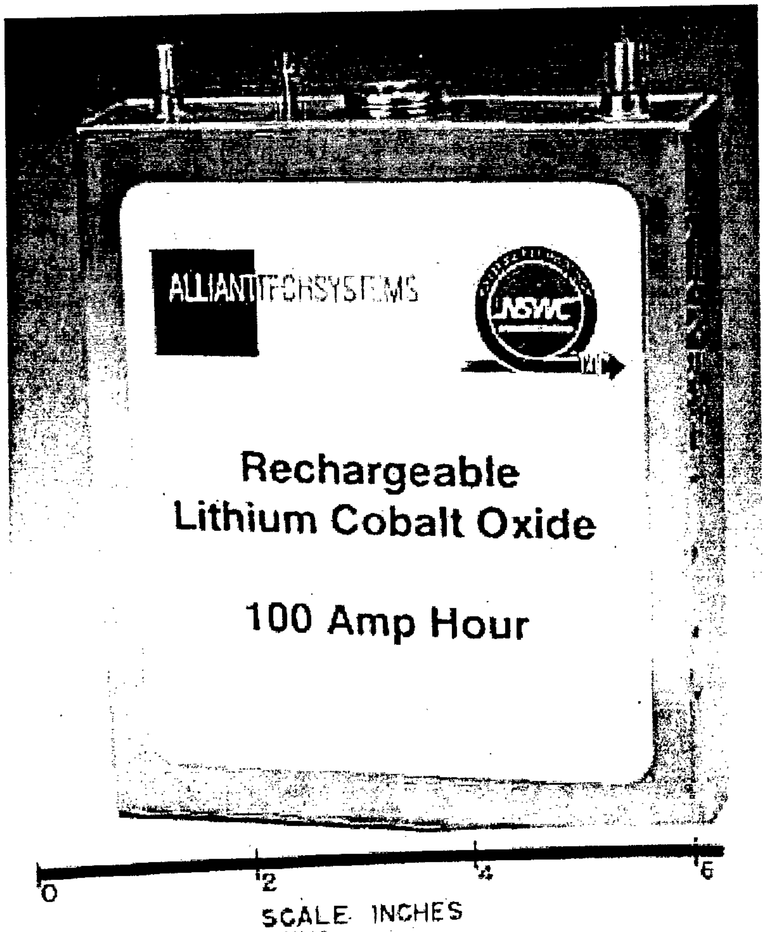

Figure 1. 100 Ah Lithium/Lithium Cobalt Oxide Rechargeable Cell

2.0 REQUIREMENTS

The rechargeability of $Li/Li_{0.5}CoO_2$ was demonstrated earlier, as discussed above. The focus of the program was toward larger multi-cell modules of 600 Ah size and was modified during the course of execution to 300 Ah size cells in order to address more directly the evolving requirements of underwater vehicles. The propulsion power supply cells operate at a nominal potential of 3.9 volts (V) for $Li/Li_{0.5}CoO_2$. Actual voltage range for vehicle propulsion is 4.0 V to 3.0 V over a 6-hour period (6-hour rate to 100% depth of discharge). Cycling at greater depth of discharge will increase delivered energy and run time, but cycle life will be reduced.

The capacity and energy density of an electrochemical cell depends on the depth of discharge i.e., the percent of the total available capacity actually used on discharge. Depth of discharge is

important for underwater vehicle run time capability. For the Li/Li_xCoO_2 battery, 100 percent depth of discharge is based on a (x), in the range of 0.5 and 1.0 during charge/discharge reactions. Thus a 100 percent depth of discharge for the 100 Ah cells developed during this contract is actually cycling the cell within a capacity window that is 50 percent of the theoretical capacity. When that capacity is obtained in one hour, it defines the C rate for the purpose of this report.*

Seawater temperatures range form –2 to 35°C. The real challenge to electrochemical cells is in maintaining performance at the lowest temperature requirement. Capacity per cycle and cycle life at –2°C are a required benchmark for the $Li/Li_{0.5}CoO_2$ battery technology.

3.0 BATTERY DESIGN APPROACH

Previous work[1] outlined specific materials and component processes that were advantageous to cell performance enhancement in the current contract. The materials and component processes are described below in subsections 3.1 and 3.2 respectively and reflect updated information since the time that the 30 Ah cell development has been added. New materials have been added in some cases or a more cost-effective source of supply identified. Following that, subsection 3.3 describes design features of the developed 100 Ah cell.

3.1 Materials

Electrolytes

The following electrolyte components were used as received: Lithium hexafluoroarsenate ($LiAsF_6$), Electrochemical, LaRoche; carbon dioxide (CO_2), Bone Dry, Toll Co., and methyl formate ($HCOOCH_3$), Alliant Techsystems' specification, E.M. Science Co. lithium tetrafluoroborate ($LiBF_4$), Electrochemical, Cyprus Foote Mineral Co., was dried at 80°C under vacuum (200 millitorr) for 16 hours, minimum.

Solutions were prepared in a glove box under argon. $LiAsF_6$ and $LiBF_4$ were dissolved in methyl formate to obtain concentrations 2.0 molar (*M*) in $LiAsF_6$ and 0.4 *M* in $LiBF_4$. The solutions were then saturated with CO_2 by passing the gas through them at a pressure of 30 pounds per square inch, gage (psig) for at least 30 minutes. Typically, they had less than 50 parts per million (ppm) of water, as measured by a Photovolt Model 128 Fischer Titrator.

Electrodes

Anode - Lithium Foil, (Li, 99.9% minimum) FMC Corporation, Lithium Div., was purchased in 0.006 inch thickness and die cut to area dimensions of the electrode.

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* C/n Ratings--These ratings describe a common practice to represent charge and discharge rates. That practice describes the rate in amperes, in terms of the number of hours, n , required to charge or discharge the cell capacity, C_M,

$$I = C_M/n$$

The capacity, C_M, is the total ampere-hours delivered to a given cutoff voltage over the period of M hours. M is often 1 but 5, 6, and 20 are also common to some systems.

Cathode Components - Used as received were:

- Lithium cobalt dioxide ($LiCoO_2$), lithium cobalt (III) oxide, FMC
- Carbon (C), Cabot Corp., type Vulcan XC-72R (98.5%), (characterized by a surface area of 254 square meters per gram (m^2/g) and a particle size of 30 microns); and
- Polytetrafluoroethylene ($[-CF_2\ CF_2-]_n$), DuPont Corp., Teflon-30, (an aqueous emulsion, 60% solids).

Separators

Microporous, polypropylene/high density polyethylene/polypropylene/polyethylene trilayer separator, Hoechst Celanese Corp, Celgard 2300 was dried under vacuum (200 millitorr) at room temperature for a minimum of 16 hours prior to use. Three layers of this separator were used between the anode and cathode plates.

In the 30 Ah prior cell development[1] 3M Co. type E003 separator was used. This material was discontinued. The Celgard separator, selected to replace E003, is designed to create a high electrical resistance in the event of a temperature rise, such as that caused by a short circuit. The resistance is due to separator melting. This separation system is sometimes identified as "shutdown separator." The physical properties of the separators are listed in Table 1, by permission of Hoechst Celanese Corp.*

Table 1. Hoechst Celanese Celgard Separator 2300

CHARACTERISTICS	TYPICAL VALUE
Thickness	25.6 Microns
Shrinkage, MD (60 min. @ 90° C)	4%
Tensile Strength MD TD	1487 Kg/cm^2 167 Kg/cm^2
Gurley	

Inert Metal Components

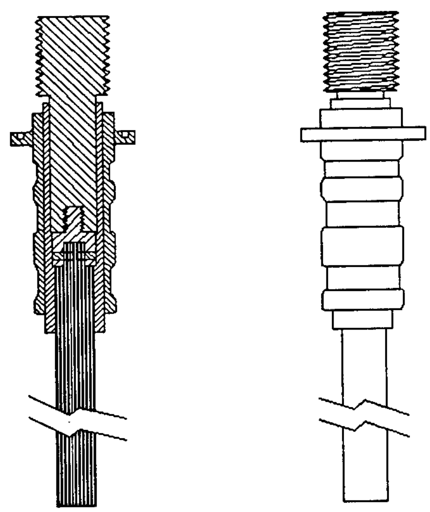
The inert metal components include the electrode current collectors, cell cases, headers, and feed-throughs. These metal parts were washed with deionized water (H_2O). The cleaned parts were then vacuum dried at 200 millitorr and 125°C for a minimum of 16 hours prior to use.

Current Collectors. Cathode collectors were made of expanded aluminum (Al) metal grid (Delker Corporation's type 5AL 17-125). Tabs of aluminum (type1100) were ultrasonically welded to the grid for use as electrical leads. Anode collectors were grids formed from nickel foil 200 using an electro-etch process manufactured by Lancaster Metals, Lancaster, PA. The anode individual collector grids are 0.002 inch thick.

* Hoechst Celanese Battery Application Data Sheet, Separations Products Division, 13800 South Lakes Drive, Charlotte, NC 28273.

Cell Cases. Prismatic cell cases were fabricated by Trenton Sheet Metal Co. from type 304 stainless steel (SS). They are of welded seam construction, as a cost-effective way of avoiding the high cost of deep draw forming tools that would be used in production. There is a weight penalty attached to welded seam construction.

Headers. Case headers were of type 304 SS. The glass-to-metal (GTM) seal generally used to isolate battery terminals from the header was used for only the anode terminal. A compression seal was used for the cathode terminal. Compression seals have been shown very effective when properly designed.[4] A sketch of the seal, designed by Alliant and manufactured by THREE E Labs, is shown in Figure 2 and a drawing in Appendix C. The insulating material between the aluminum positive terminal and the header was Tefzel.* The seal had an additional feature that provided multiple tabs for cell internal connections. Multiple tabs enhanced the ability to make high quality ultrasonic tab welds.



Section View

Figure 2. Compression Seal Used in the 100 Ah Cell.

3.2 Processes

Cathode Process for Basic Effort

Much of the beginning effort of this contract was directed toward scaling-up and further developing a cathode manufacturing process that would perform as well as or better than the dry formed cathodes produced during the 30 Ah cell development. It was evident early in the development that the much larger area cathode needed for the 100 Ah cell did not lend itself to

* duPont's polymer, ethylene tetrafluoroethylene.

a press forming process alone, as was the case with the 30 Ah cathode. The amount of press force needed to apply the same unit area force as was applied to the 30 Ah cathode was prohibitively high from a machine standpoint. Consequently, a wet process, using mill rolling with thickness reduction steps evolved. Prior to mill rolling, several steps of mixing of raw materials were necessary to obtain the right consistency for mill reduction. The mixing steps were developed as follows:

- Muller mixing of $LiCoO_2$ powder and Vulcan XC-72R at a ratio of 87% to 9.7% respectively. The batch size at this step is 11.12 lbs.

- The next step involved making an aqueous dough with 3.3%Teflon 30 added as a binder to maintain body as the material was rolled into a cathode sheet.

The cathode loading percentages identified above were identical to the cathodes made and used in the 30 Ah cell program. Two other cathode parameters, which departed from the 30 Ah experience, were final cathode density and cathode plate thickness. These parameters were aggressively sized upward to achieve a drawing design, energy density of greater than 7100 Wh/lb for the 100 Ah cell. Average 30 Ah cell cathode density and thickness are compared with average 100 Ah cell cathode density and thickness below:

	30 Ah Cell	**100 Ah Cell**
Cathode density	2.37 g/cc	2.7 g/cc
Cathode thickness (double side)	0.027 inch	0.060 inch (later returned to 0.029)

Cathode Pad

Cathode pads were made by passing the kneaded cathode mix through a roll mill six times at a gap setting of starting at 0.080 inches. After every two passes, the pad was folded in half and rotated 90 degrees. This procedure was repeated several times, except that the roller gap setting was reduced every six passes until a final setting of 0.015 inches was reached.

Cathode Pad/Current Collector

Cathode pads were rolled onto both sides of the expanded metal collectors at a gap setting of 0.027 inches followed by drying at 200°C for at least 16 hours. Pad dimensions exceeded those of the current collector. The final cathode dimensions were obtained by die cutting the finished composite pads and expanded metal grid collector. The drawing package shows final dimensions for the cathode. Finished cathodes were vacuum-dried at 170°C for a minimum of 16 hours prior to use.

Cathode Performance Evaluation

As cathodes were produced, quality checks were made by building and cycle testing laboratory cells constructed of 0.50 square inch area cathodes. These lab cells required mechanical adjustment and several cells were built before the technique was perfected enough to give reliable test data. Typical lab cell configuration and test results are shown in Figures 3 and 4. During these lab cell tests, we also tried to judge the effects of electrode plate compression, including 0%, + 10% and -10% (or relaxation). The last is gap or expansion allowance of 10%.

The results were inconclusive except to note that degrees of compression or relaxation at extreme levels can degrade performance. Too much compression (>10%) and too loose a pack (<10% expansion allowance) can cause cycle life to fall off. During the build of the Basic Effort 100 Ah cells, stack compression was deliberately varied and performance tracked. As a result, it was judged that an allowance for 6% expansion (measured from the initial as built stack thickness), was least detrimental to cycle performance. All cells built at the end of the Basic Effort lot construction and through the balance of the program had 6% expansion allowance as part of standard assembly practice. Smaller cells; i.e., lab cells and 8 Ah flat plate cells (See Section 5) do better than full 100 Ah cells. Other variations in material and design make it difficult to make a judgment about compression from this study.

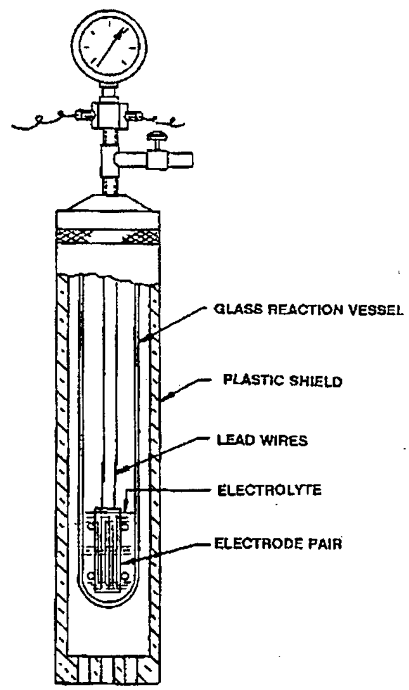


Figure 3. Standard Laboratory Cell

Anode Process

Lithium foil, 0.006 inch thick was die cut for pressing on each side of the current collector by rolling. First, one piece of lithium was rolled onto one side of the collector. A second piece was then rolled onto the opposite side. A portion of the lithium is extruded into the opening in the electro-etched grid metal; the final anode thickness was .013 inches. Further discussion on special design features added to the anode electrode can be found in subsection 3.3.

Ultrasonic Welding Process

To date, only aluminum was found suitable as the collector material for the $Li_{0.5}CoO_2$ cathodes because of its high conductivity and corrosion resistance at high charging potentials. This requirement, however, presents a challenge in welding Al-to-Al (specifically, leads and spacers to the bus bar). The use of resistance welding was found highly unreliable because of the oxide layers on aluminum surface.

Excellent bonding of Al-to-Al was achieved by using an ultrasonic weld technique. No electrical current is passed through the joint, and the amount of heat produced is insufficient to affect the mechanical and metallurgical properties of the aluminum. In ultrasonic welding, high-frequency power is converted into vibratory power by a transducer, to which the welding tip is attached. The welding tip oscillates in a plane essentially parallel to the joint interface. Transverse (shear) waves in the two adjoining surfaces break the oxide layers and produce the weld. Since cathode current collectors and electrode tabs are aluminum, ultrasonic welds were necessary to connect them together in the electrode plate. Tabs (30 each) were connected to the external terminal via the compression seal (Figure 2).

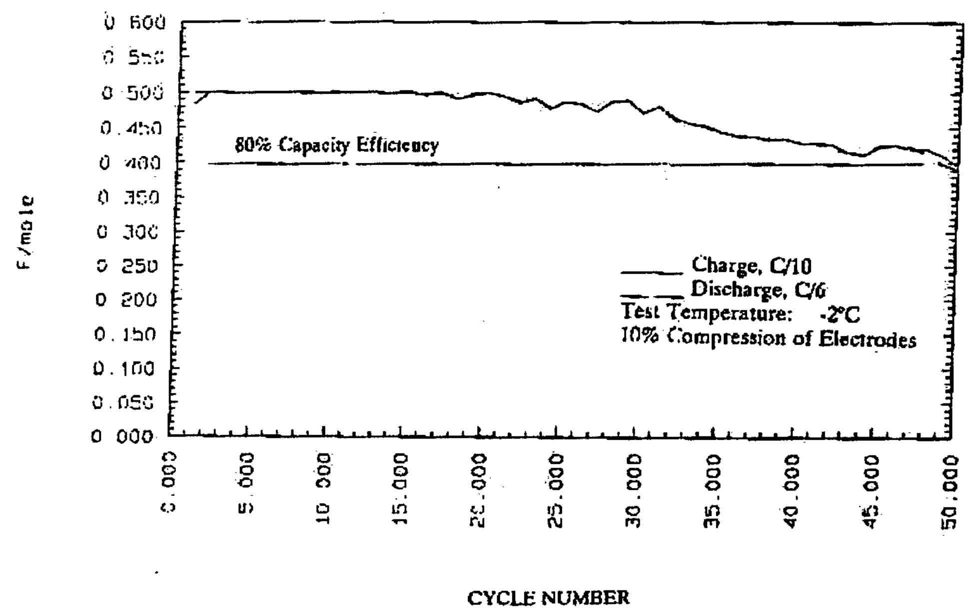


Figure 4. Lab Cell NSWC17 Performance

3.3 Design Features

Retrofit to SDV Battery

The 100 Ah cell (sub-SDV cell), Figure 1, embodies all scale-up features of an engineering baseline SDV cell with regard to electrode size and weight. It is a sub-SDV cell only because the number of electrically paralleled plates is equivalent to 100 Ah capacity. The sub-SDV cell's external width and height are full scale; only the length is increased in a full SDV cell to accommodate more plates. The 100 Ah cell is designed for continuous cycling at 100 percent of its rated capacity. The goal was to provide 50 cycles (6 hour discharge/10 hour charge) with an energy density of 100 Wh/lb. Accomplishing this goal would be a factor of two improvements over AgO/Zn electrochemistry, currently in use. Since the $Li/Li_{0.5}CoO_2$ battery retrofits the existing SDV battery, it was necessary to duplicate the present weight of the battery at 776 lbs. The $Li/Li_{0.5}CoO_2$ cell has been designed to take maximum advantage of existing tray volumes without exceeding the filled tray weight. Operating temperature range for the battery and consequently the sub-SDV cell is –2°C to 35°C. Voltage compatibility with the existing vehicle

battery was also important. Consideration needed to be made for the difference in electrochemical potential between the existing AgO/Zn cell at 1.5 V and the $Li/Li_{0.5}CoO_2$ cell at 4.0 V, to maintain vehicle voltage at the required 128 V. To accomplish this, the modular approach was taken. Four series connected modules, each composed of two, 300 Ah $Li/Li_{0.5}CoO_2$ cells per tray, are equivalent to the same tray with 10 AgO/Zn cells. Both electrochemistries are then 15 to 16 V, open circuit potential.

Innovative Technology

During the development of the 100 Ah cell, many new features were introduced. Two U.S. patents have resulted.[5,6] The first involved the synthesis of pre-charged $Li_{0.5}CoO_2$ for use in reserve battery applications. Although not specific to vehicle propulsion use, they have advantages to military applications. The second patent improved the design of the flat plate anode. When multiple plates are paralleled together as in the case of the 100 Ah, high numbers of cycles tend to produce inefficiency in plating lithium. Repeated formation and dissolution of metallic lithium causes dendrite lithium to form on electrode edges, particularly the anode perimeter. The developed patent design works to abate or scavenge the dendrites in areas where they do the most harm. Improved cycle life and safety result.

Features for Performance

While improved materials were being tested for their application to 100 Ah cell performance and electrode fabrication processes as well as assembly processes were being optimized, work was proceeding on mechanical design features that would bring out the best cell package for the 100 Ah $Li/Li_{0.5}CoO_2$ SDV cell configuration. The following subsection describes observations of cell behavior that limited performance, and solution seeking design features implemented. Design parameters were evaluated using two different cell designs: a 12 Ah subcell and the 100 Ah full cell. Other than the number of plates used in the cell stack, the designs of the cell stack and internal hardware were identical.

Features for Safety

Moving the program from the cell development stage to a battery integration phase required the need to address system safety. In the case of multiple cell batteries, system management of cells in series and parallel is a challenge particularly during charging. The management system not only monitors the state of charge of the individual cells in the battery but also allows for electrical bypass of cells, which have reached full charge or are not operating satisfactorily. Complete shut-off of cells that show abnormal behavior is a mandatory feature of any high energy, large capacity system. This is particularly true of an electrochemical battery that combines flammable electrolyte, moisture reactive lithium metal, physically expanding electrodes, and internal gas pressure that may increase during normal operation. Therefore a program task was to design and demonstrate a suitable electronic circuit that would provide all of the features of charge monitoring and control, and safety shut-off on discharge and abnormal temperature. The result was an individual circuit board Smart Battery Interface (SBI) on each cell that allows for cell replacement when retirement of a single cell in a battery becomes necessary. While aspects of the design address safety as suggested by analysis or preliminary testing, the scope of the present work did not include full-scale safety evaluation of the final product.

Component Testing Using Fixtures

As testing proceeded, the multi-plate prismatic electrode design evolved into a stacked configuration of 31 rectangular anode electrodes, and 30 rectangular cathode electrodes. Many additional questions relating to such things as the grade of $LiCoO_2$, electrolyte composition, electrode interface, separator choice, and dendrite control had to be addressed. Early work with 12 Ah flat plate cells tried to answer some of the questions. Design resulting in the best performance was then carried over to the 100 Ah cells. Performance evaluation continued with safety and cycle life improvement as a major goal. A set of design features resulted that set the stage for the characterization testing that followed. Summarized below are the most important design features:

Stack Compression

Control of the cathode and separator compression using the spacers adjusted to internal case width and stack height. A 6% oversizing of the case during assembly benefits stack insertion and helps prevent misaligning the rectangular electrodes while sliding the stack into the case that is open only at the terminal end.

Anode Expansion

The stack of electrodes expands on charging because lithium from within the cathode active material is transferred to, and plated onto the anode. Because the cell is built in the discharged state, the first plating accompanies the initial charge. Space can be allowed for this by design, that is, by the extent of compression on the stack. The extent of expansion, however, increases with cycle life because the deposited lithium can react to form more voluminous products at the electrode surface. Aurbach* and others have studied these surface products. In any case, three significant observed effects are:

- An increase in thickness of the anode plates which causes stack swelling. In the case of the multiple flat plate 100 Ah cell design, the expansion force, as a result of restrained swelling, (see Figure 5), has been observed to more than triple in cells from the discharged state to the charged state. A change of 24,000 pounds force was measured.

- Cell resistivity increases by an order of magnitude over cycle life. In the case of multiple flat plate 100 Ah cell stacks, static 1,000 Hz AC Impedance checks that measured 14 milliohm AC impedance at the beginning of life reached 140 milliohm after 40 cycles.

- Edge expansion and dendrite growth cause separator penetration and localized soft shorts. These effects raise safety concerns.

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* The nature of lithium metal anode surface as it changes with cycle life progression have been studied by Aurbach, *et al*, among others.[7] They describe lithium surface films composed of species of electrolyte solvent reduction, salts, and dissolved gases. The gases could be atmospheric contaminants or purposely added gases for cycling benefit. Appearances of the uncontrolled anode surface during the dissolution and plating of lithium ions are three-fold in nature: first, increased surface area due to the lithium metal surface roughness, created by the reaction process; second, electrode perimeter enlargement as deposition seeks electrode edges; and third, accumulation of spalled dendritic lithium from suspension in the liquid electrolyte onto bare surfaces, such as current collecting tabs of the anode plates.

Shorting Protection

The 100 Ah cell has over 60 linear feet of anode electrode edge that is susceptible to deposition thickening. Edge shorts have been directly related to low cycle life. Plated lithium on electrode edges had been measured at twice the thickness of the original anode thickness after only 25 cycles.

Three design solutions were created to counteract the dendrite shorting problem created by edge plating:

1. The cathode is enveloped between with two layers of heat sealable microporous separator, Celgard 2300;

2. The cathode plate is die cut smaller than the anode plate size. Postmortem of cycled cells gave strong evidence in favor of using undersized cathode plates. The layer of dendritic lithium plated around the edges of the anodes was thinner and more uniform in the case where the cathodes are sized smaller than the anodes; and

3. A graphite frame[6] was added on both sides of all boarders of the anode electrode plates as shown in Figure 6. The evolution of the electrode profile and multiple interface is depicted in the 100 Ah cell cross sections, Figure 7, beginning with the earliest on the left and the current design on the right. The edge was protected from dendrite shorting because, on charge, lithium was deposited into the graphite structure, eliminating thick build up. The interior surfaces of the anode plate remained a cold-rolled lithium metal directly in contact with the current collector grid. Lithium can intercalate into and out of the frame. It was observed that the graphite frame, supported by an extended anode current collector, turned a yellowish-green color indicating intercalation after repeated cycling. Examination after 60 cycles, when suspended on a discharge half cycle, found the frame to contain 25 weight percent of lithium. Based on 100 Ah cells cycled with and without graphite frames, cycle life improvement appeared to be 25 to 30 percent. Postmortems of cell stacks showed a noticeable absence of free-floating dendrites from those observed with unframed anodes. More uniform current distribution and, therefore, more efficient utilization of the active materials form plate-to-plate was obtained through the use of properly positioned bus bars and tabs. To achieve this design objective, good bonding of leads and spacers to the bus bars was critical. Please see section on ultrasonic welding above.

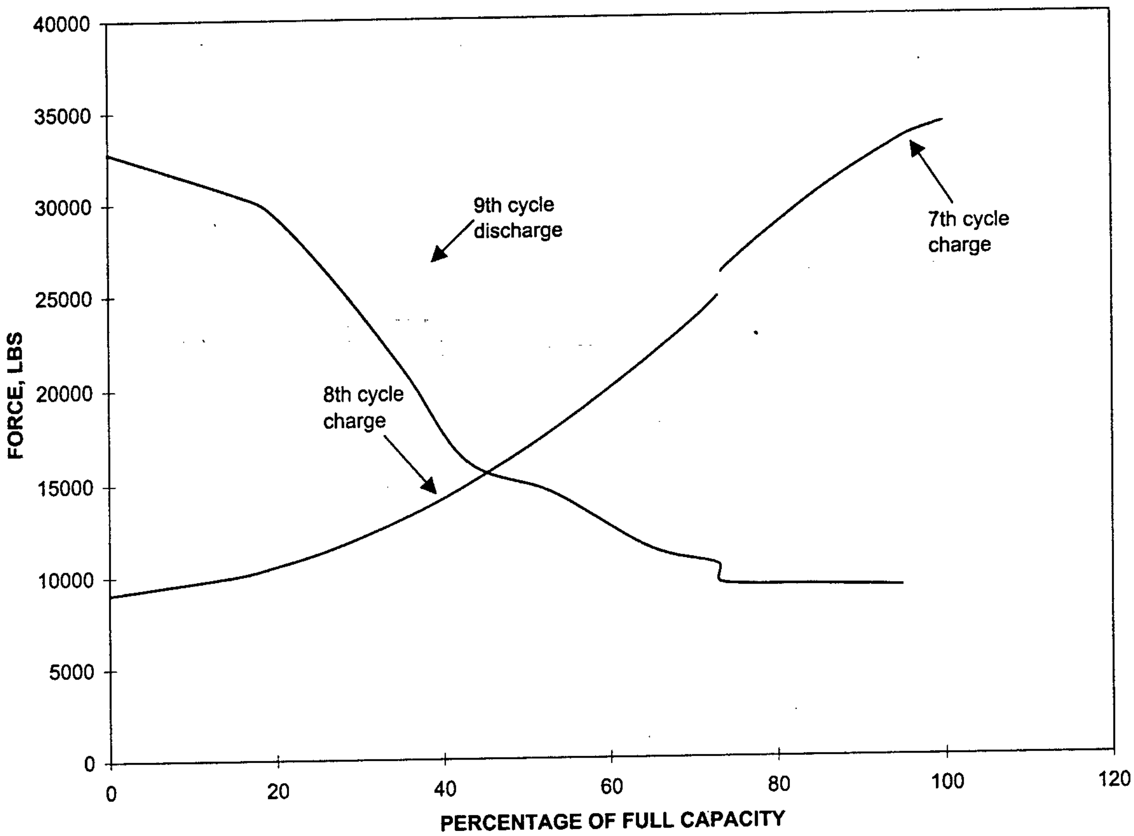


Figure 5. 100 Ah Cell Swelling Force During Charge and Discharge

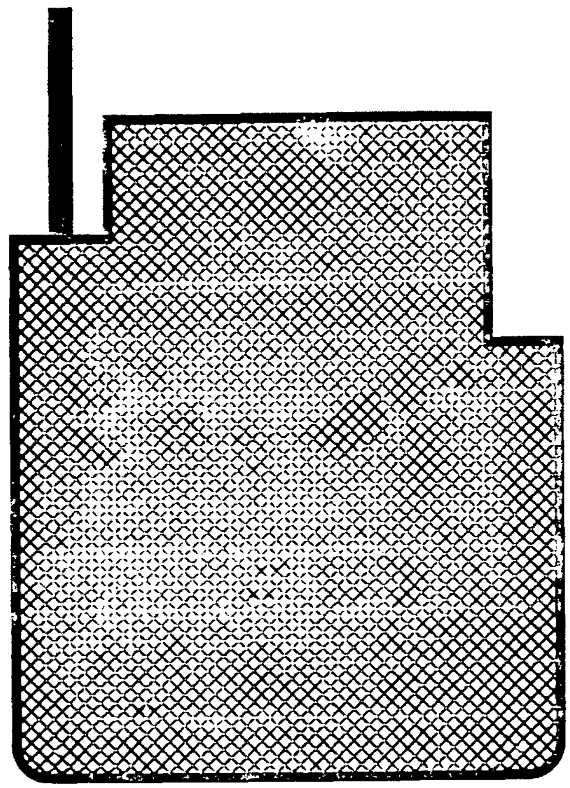


Figure 6. Anode Current Collector with Graphite Frame

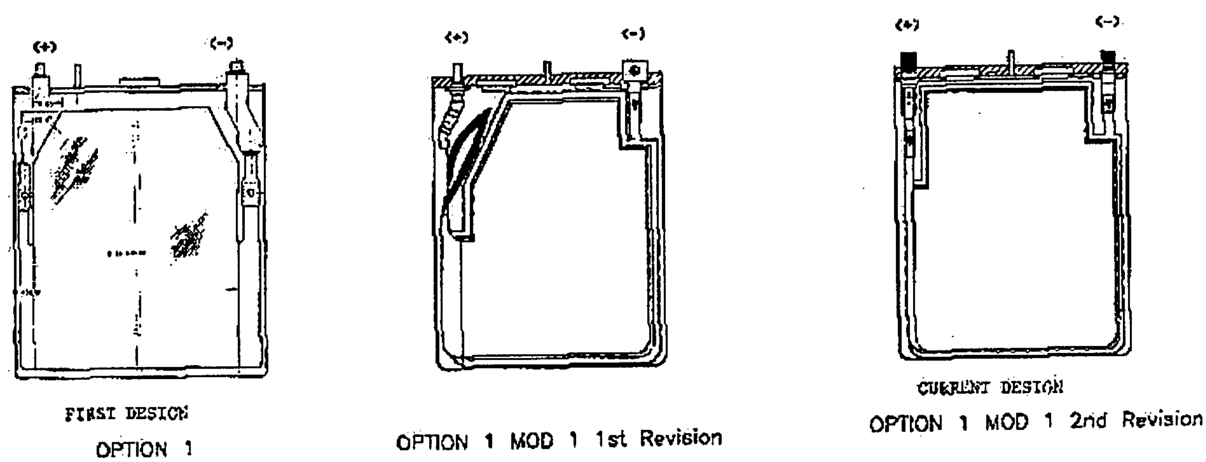


Figure 7. 100 Ah $Li/Li_{0.5}CoO_2$ Cell Cross Section Evolution

Electrolyte Optimization

For the electrolyte, 2 *M* $LiAsF_6$ + 0.4 *M* $LiBF_4$ salts are dissolved in the highly conductive solution methyl formate in which CO_2 (gas) is added. The high conductivity characteristic is particularly beneficial for the cold temperature service required in underwater vehicle operation. The selected salts for the electrolyte include 2.0 *M* lithium hexafluoroarsenate for its stability and non-reactiveness with the lithium anode. Lithium tetrafluoroborate, on the other hand, is added in lesser amounts, 0.4 M, and contributes to cycling efficiency. Lithium tetrafluoroborate does react with the lithium surface. Lithium cycling efficiency of batteries with this electrolyte is poor without the addition of bone-dry carbon dioxide gas.[8] Li_2CO_3 is formed on the lithium anode surface by the CO_2 addition. This surface film protects and passivates the lithium and extends cycle life. Solutions of methyl formate solvent and carbon dioxide gas have doubled cycle life from ten years ago when the same electrolyte without CO_2 was noted to provide no more than twenty cycles.

Safety Features

Vents. A reverse frustum-buckling disc manufactured by BS&B was used in the 100 Ah cell header. To avoid any heat effect during welding, the disc is pre-welded into a housing and the entire assembly is then heat treated to either partial or full anneal condition. For partial annealing, the parts were heated under vacuum from room temperature to 800°C in 1 to 1.5 hours and held at 800°C for 1 hour before switching off the furnace cooled them. These vents open at a nominal 325 psig. In the fully annealed case, the vacuum furnace was heated from room temperature to 1052 to 1070°C in 1.5 hours. The parts were held at this temperature for 1 hour, and then force-cooled by nitrogen gas.[8] These vents open at 350 psi. For this program, we used the partially annealed vents.

Other Safety Features. These include the "shutdown separator," graphite frame on the anode and the electronic controller discussed above. Other features include the use of a flash-back arrestor (flame arrestor matting), teflon coating of exposed container surfaces, and overall cell design to readily permit venting through access areas as shown in Figure 8.

*Electronic Control**

Electronic charge control, cell monitoring, and capacity data storage capability of 100 Ah cells was added to each cell individually. Batteries composed of electronically controlled cells were also electronically coordinated to be controlled in series/parallel connected battery arrangements. Uniquely, this was all accomplished at high propulsion power levels. The criteria were:

> Electronic control with circuits capable of handling the high electrical current of each 100 Ah cell. Currents were on the order of 20 amperes per cell.

* The task for the electronic design and demonstration of the Charge, Monitor, and Control system was the effort of DaTran Corporation under the direction of Alliant Techsystems. DaTran's Operations Manual, and System Description is reprinted in the Appendix.

Individual, stand-alone control of each cell in a battery matrix, with "On-Board" electronics on each cell, rendering each cell "change-out" capable in a battery scenario consisting of hundreds of cells per ship set.

Control logic for cells is explained in Section 5.0 of this report.

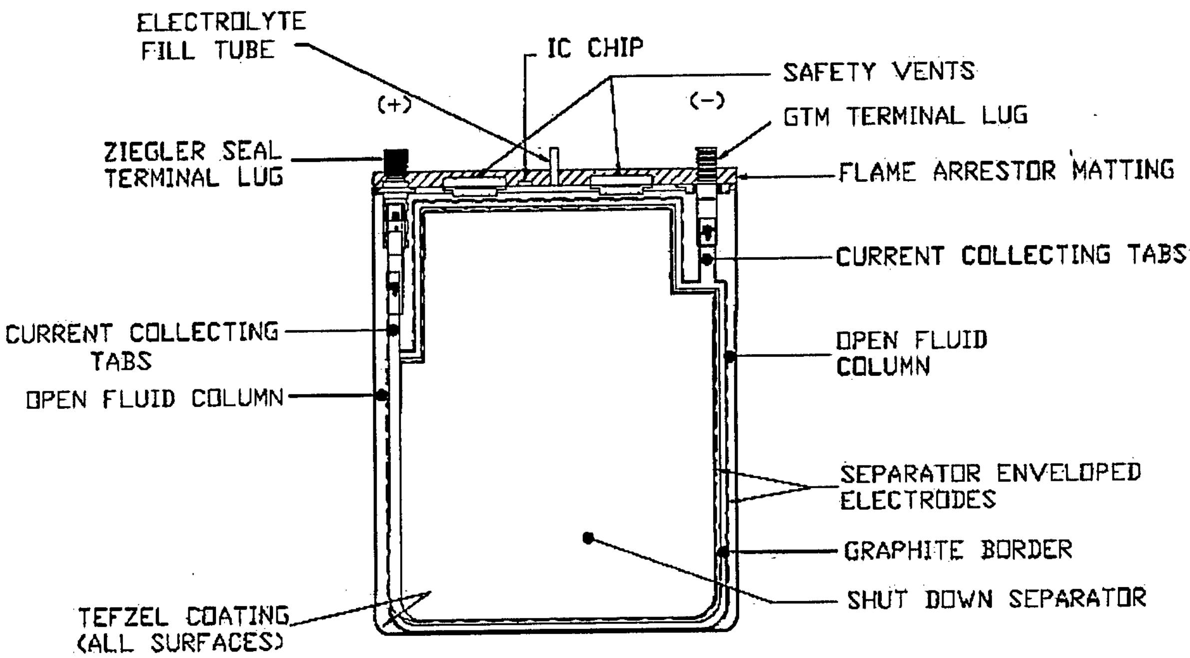


Figure 8. Design Safety Features Shown in 100 Ah Cell Cross Section

3.4 Cell Capacity

The present design provides cells rated at 116 ± 2 Ah based on 90 percent of the calculated capacity, assuming ½ F/mole, i.e., 0.9 (½ F/mole). However, and with probable sacrifice in cycle life, a maximum of 0.55 F/mole can be obtained which would result in a capacity of 142 Ah.

At present, the cell weighs 5.8 lbs, but the cell case is overweight because it is made from heavy gauge sheet metal to facilitate hand weld fabrication. Deep drawn cases would be lighter and stronger. Thus, energy density can be expected to improve in production quantities due to a higher level tooling commitment. Likewise, anode grid foil can be decreased in thickness with proportional weight savings. A cell weight of 5.25 lbs can be projected. Corresponding energy densities are as shown below:

	Capacity, Ah	Capacity, Wh, @ 3.85 V	Energy Density, Wh/lb, assuming a 5.8 lb cell	Energy Density, Wh/lb, assuming a 5.25 lb cell
Rated	116 ± 2	447 ± 8	78 ± 1	86 ± 1
Calculated	129 ± 2	497 ± 8	85 ± 1	95 ± 1
Maximum	142 ± 2	547 ± 9	94 ± 1	104 ± 2

4.0 CELL AND BATTERY TESTING

Development of large capacity lithium/lithium cobalt oxide cells for naval electric underwater propulsion was on track prior to the current effort. Significant accomplishments had been made, but more optimization and characterization were needed. Up until this point, Alliant Techsystems had built, tested and documented 18 rechargeable cells of 100 Ah capacity. This followed successful programs in which 8 Ah and 30 Ah cylindrical cells of the same electrochemistry were demonstrated. Each development build and test execution, regardless of cell size, was followed by postmortem examination and documentation of the cells. It was through this iterative process that improvements were made in the design and assembly techniques. The original experimental design intent was to build a rectangular cell large enough such that all of the challenging effects of the electrochemical system could be observed in a cell with field useful energy levels. Even larger scale-up would then be only an increase in the number of paralleled electrode plates needed to build a cell of the desired capacity. This "design of experiments" approach appears to have been a wise choice in the case of the 100 Ah cell. Observed characteristics, both good and bad, are the same as those expected in much larger cells. The 100 Ah cell itself has useful underwater propulsion applications. For this reason, it merited not only further optimization but characterization of the optimized design. Characterization would provide needed parametric data to help users access its capability in specific applications.

Beginning efforts in the program used smaller cells to test some of the design changes. Figure 9 is substantiation that some of the changes tested in smaller cells, 12 Ah (flat plate, full electrode) cells showed improvements expected to carry over to the 100 Ah cell. Significant improvements in cycle life were noted and a 90 percent depth of discharge was maintained throughout the testing. Some of the major items tested included: thinner cathodes, alternate separator material, and molarity reduced electrolyte. The encouraging results of the 12 Ah cell tests left us positioned to duplicate; particularly cycle life longevity and energy density, in the 100 Ah cell size. It was not too ambitious to project that successful duplication of the 12 Ah cell results in the 100 Ah cell would bring the 100 Ah cell to a level of usefulness for underwater propulsion applications by the Navy. Characterization studies in the work described herein may well prove to be the bridge between the developmental 100 Ah cell of a new electrochemistry and a developed $Li/Li_{0.5}CoO_2$ cell ready for useful underwater propulsion trials.

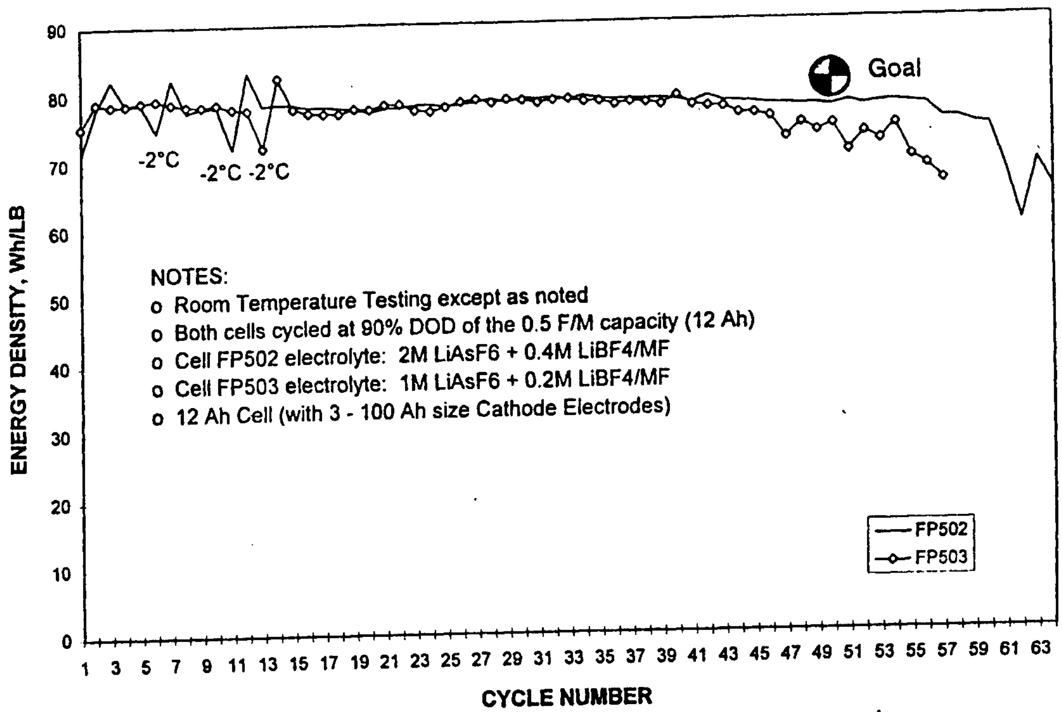


Figure 9. 12 Ah $LiCoO_2$ Rechargeable Cells Demonstrating Performance Resulting from Design Modifications

4.1 Test Equipment

The cells in the characterization study as well as the development cells that preceded the study were all tested on Maccor* Series 2000 battery test system. The versatility of the machine allows testing of primary cells and continuous cycling or individual charges or discharges as desired in the case of secondary cells. This sub-section does not address the test equipment used in the Smart Battery development part of this contract. A description of the Smart Battery testing will be treated separately in a later sub-section.

4.2 100 Ah $Li_{0.5}CoO_2$ Cell Characterization Test Plan

The test plan for a build of a single lot of 30 cells was prepared with the understanding that every possible characteristic of the baseline design of the 100 Ah cell could not be statistically documented in such a small lot quantity. It was hoped that a consistent build could be achieved such that test data would not be masked by variations in hand building techniques and operator error. The dedication of only 2 cells per test type was all that the build quantity allowed due to program funding constraints. The initial test plan is shown in Table 2. A contingent plan, not documented, was to continue the decision-making process during the course of testing to allow shifting of cells to tests where more data was wanted. Also, in attempting to understand characterization trend; past 100 Ah cell test results, prior to the 30 cell build, were examined for supportive or detractable data.

* Maccor is an independent corporation based in Tulsa, Oklahoma.

Table 2. Plan for Characterization Testing of 100 Amp Hour $Li_{.05}/CoO_2$ Rechargeable Cells

TEST NO.	CELL NUMBERS	TEST DESCRIPTION
1	703, 704, 712 718, 717, 719,723	Baseline Charge - 10 hr rate; Discharge - 6 hr rate ("baseline rates") Cycle to 80% of rated capacity (r.c.) * Temp. 25°C
2	725	Cycles 1 & 2 - Baseline rates Cycles 3 to 80% of r.c. Charge - 20 hr rate; Discharge - 6 hr rate Temp. 25°C
3	729, 730	Baseline rates cycling to 80% of r.c. -2°C ± 3°C temp.
4	none	Baseline rates cycling to 80% of r.c. 35°C ± 3°C temp.
5	714	Cycles 1 & 2 - Baseline rates Cycles 3 to 80% of r.c. Charge - 10 hr rate Temp. 25°C Discharge - 6 hr rate, 2 hr max.
6	720, 722	Cycles 1 & 2 - Baseline rates Cycles 3 to 80% of r.c. Charge - 10 hr rate Temp. 25°C Discharge - 6 hr rate, 4 hr max.
7	727 after baseline	Cycles 1 & 2 - Baseline rates Cycles 3 to 80% of r.c. Charge - 10 hr rate Temp. 25°C Discharge - 6 hr rate Pulses after 1 hr : 50A 2 hr: 70A 180 sec 3 hr: 85A for each 4 hr: 100A pulse 5 hr: 125A
8	721, 724	Cycles 1 & 2 - Baseline rates Cycles 3 to 80% of r.c. Charge - 10 hr rate Temp. 25°C Discharge - 20 hr rate
10	728	Charge at 10 hr rate Discharge at 6 hr rate for 9 hrs - stop test (use one of 15 day stand test cells) Temp. 25°C
11	used 724 after 10	Charge at 10 hr rate for 15 hrs - no voltage cutoff - stop test Temp. 25°C (use one of 15 day stand test cells)
12	713, 715	Baseline Test Charge at 10 hr constant current, switch to constant voltage at 4.3V Discharge at 6 hr rate - to 80% of r.c. Temp. 25°C
13	709-710	Cycles 1 & 2 - Baseline rates Cycles 3 to 80% of r.c. Charge - 10 hr rate Temp. 25°C Discharge - at target profile rate
14	706-711	Cycles 1 & 2 - Baseline rates Cycles 3 to 80% of r.c. Charge - 4 hr rate Temp. 25°C Discharge - 4 hr rate
15	707-708	Cycles 1 & 2 - Baseline rates Cycles 3 to 80% of r.c. Charge - 10 hr rate Temp. 25°C Discharge - 3 hr rate
9	701, 702, 705	Cycles 1 & 2 - Baseline rates Cycle 3 - Charge - 10 hr rate Discharge - 6 hr rate for 3 hrs 15 day stand Discharge at 6 hr rate for 3 hrs Cycles 4 & 5 - Baseline rates Stop test Move cells to abuse tests 1 to overcharge; 1 to overdischarge

* Rated Capacity is 90% of Li_xCoO_2 material capacity within $Li_{0.5} \rightarrow Li_{1.0}$

4.3 100 Ah Cell Characterization Test Results - Summary*

Typical charge/discharge regimes for underwater propulsion sources were selected. The baseline regimen was taken to be a 10-hour charge followed by a six-hour discharge. This regime is test No. 1 in Table 2. As shown by the other tests in the table, variants of the baseline were also applied to more fully characterize the cell. Cycle lives up to 45 have been demonstrated. More typically, 30 cycles were obtained. This is due to less than perfect cell build consistency because of hand assembly during the development stage. Shallow cycling benefits cycle life; Cell 714 cycled at 2-hour discharges at the 6-hour rate gave 44 cycles. Because of the limited number of cells, this test was not repeated. A test at 4-hour discharge duration per cycle at the 6-hour rate vented prematurely. Longer cycle life performance, in a useful capacity range, was obtained from those cells that were charged at a 20-hour rate. A nominal 5 cycles more are attainable from 20-hour charges than 10-hour charges. Data plotted in Figure 10 substantiates the benefit of cycle life versus charge rate.

Plateau voltage or working voltage during discharge varied minimally over the range of useful discharge rates. Voltage was a nominal 3.90 V at a 33-hour rate and decreased only 0.15 V to 3.75 V at a 2-hour discharge rate. See Figure 11. High discharge rates, up to the "C" rate (1 hour) have a minimal effect on capacity; short circuit testing after 39 full depth cycles at normal design rates revealed a short circuit current of 420 amperes when shorted at the 50 percent charge level. See Figure 12. Overdischarging by 50 percent (down to 1.0 V, instead of 3.0 V) resulted in no safety incident.

A noted characteristic of cells cycling normally (a 6-hour discharge and 10-hour recharge) was the signature voltage at 100 percent charged capacity. Typically, cutoff voltage was in the range of 4.06 V to 4.16 V when allowed to float during a constant current charge. Figure 13 shows a bar chart for six voltage ranges. The high percentage of cycles in the highest voltage range (4.26 V to 4.3 V) indicates that limiting the charge voltage to 4.3 V prevents electrode damage.

Low environmental temperatures, i.e., -2°C had minimal effect on capacity. The effect of temperature on capacity and cycle life is shown in Figure 14. Cycle life, as expected, was sensitive to depth of discharge. However, cycle life is relatively insensitive to current density over 60 to 100 percent depth of discharge. See Figure 15.

* For detailed results see tabulate data in Appendix A. Figures 10-15 are plotted from these data. Cell numbers are for specific data given in the appendix.

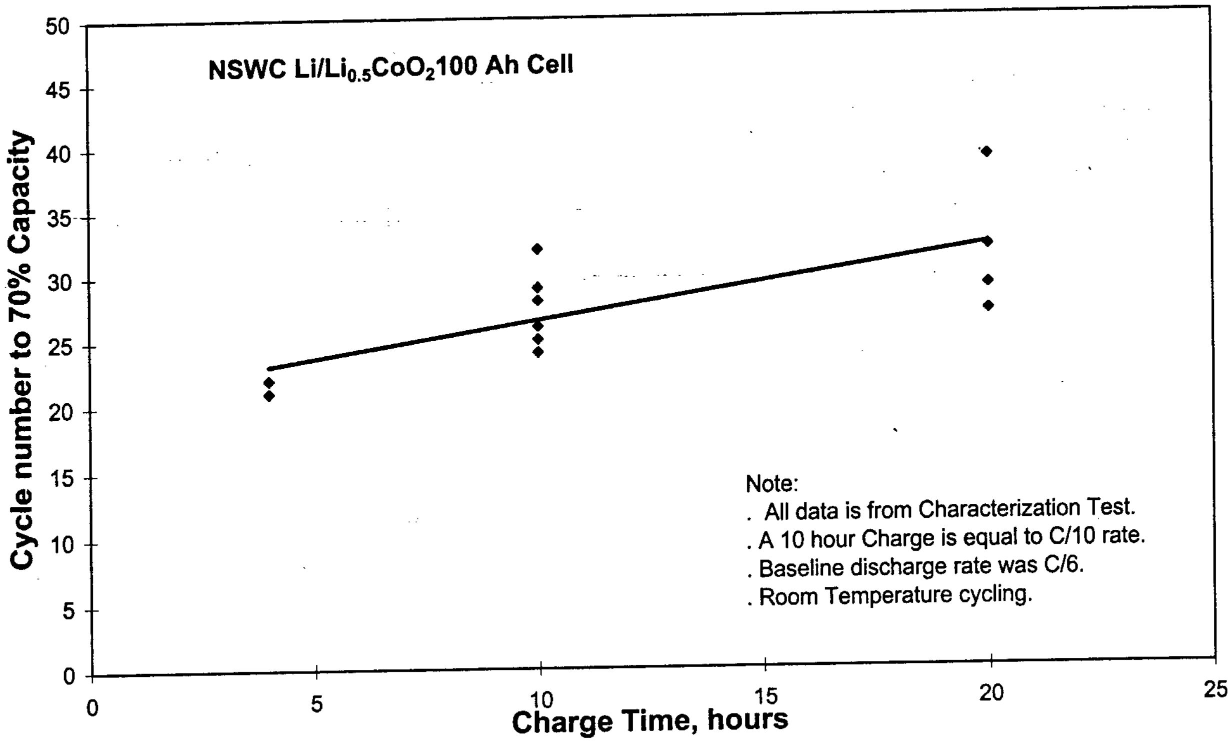


Figure 10. Cycle Life as a Function of Charge Rate

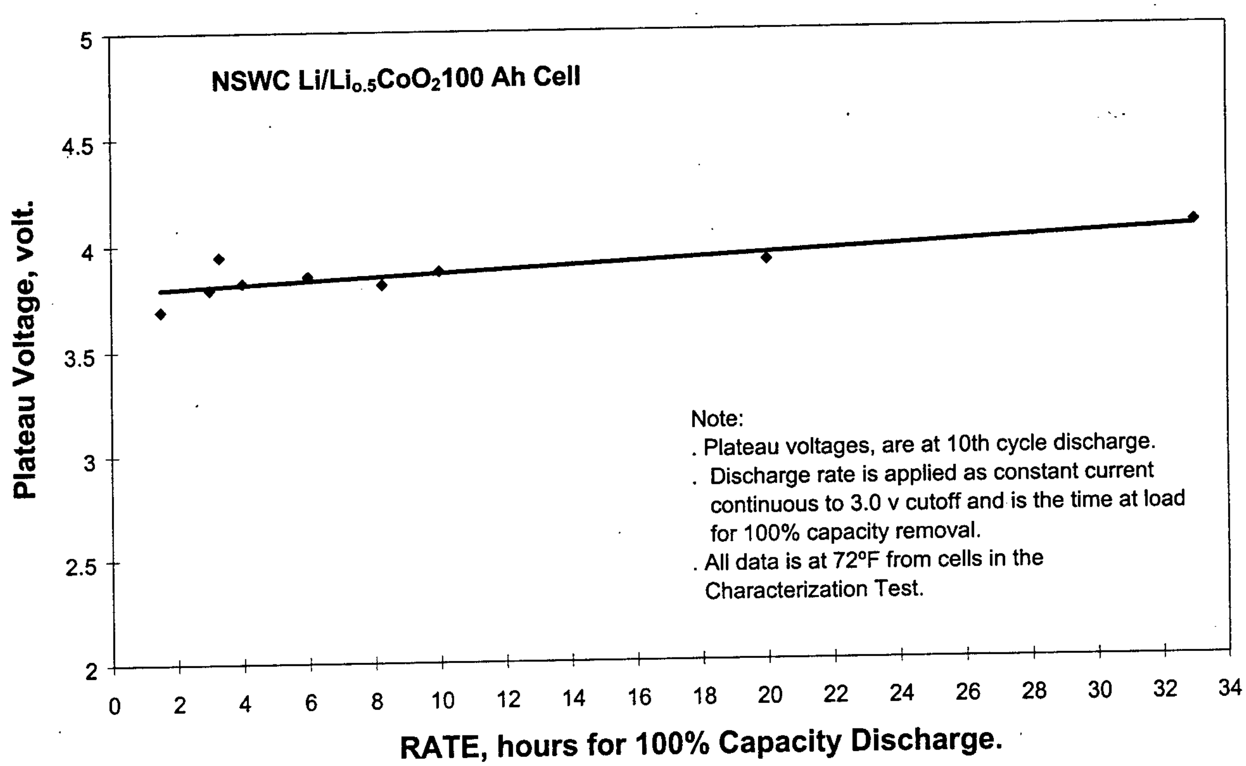


Figure 11. Minimal Effect of Discharge Rate on Working Voltage

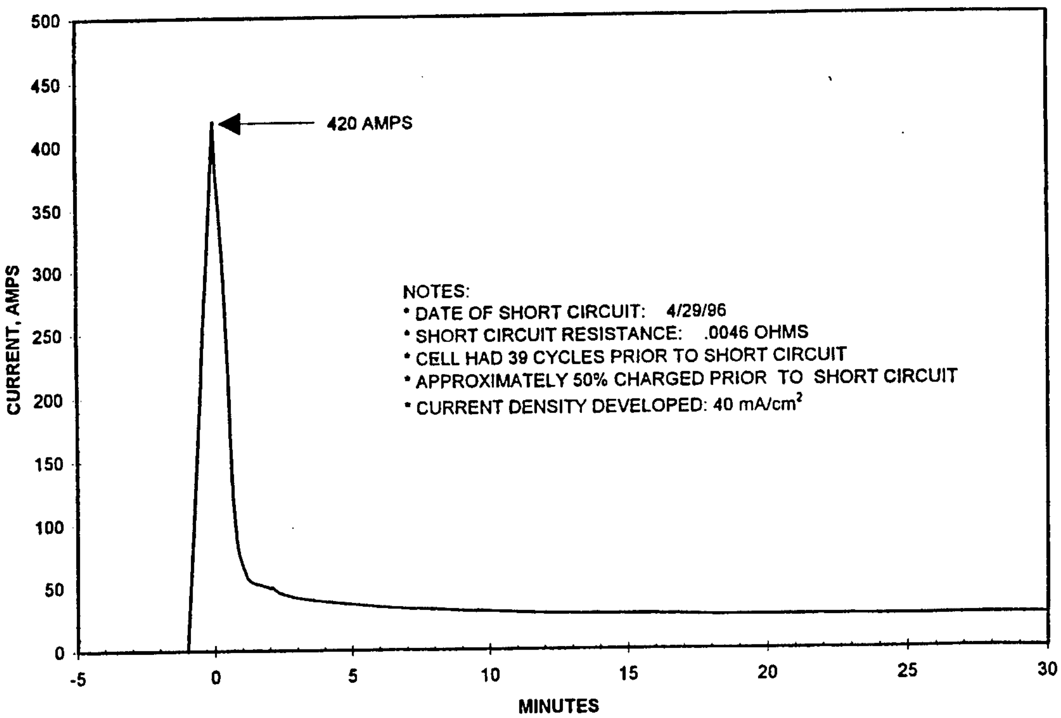


Figure 12. Short Circuit

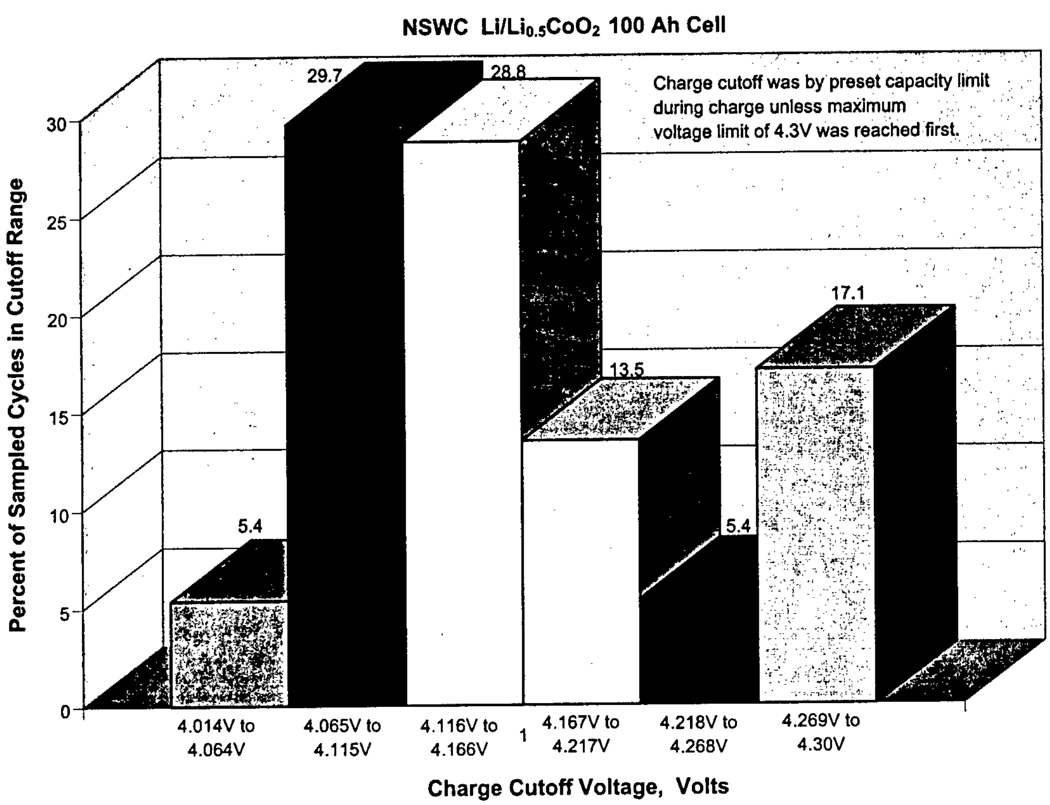


Figure 13. Charge Float Voltage Established by Characterization Testing

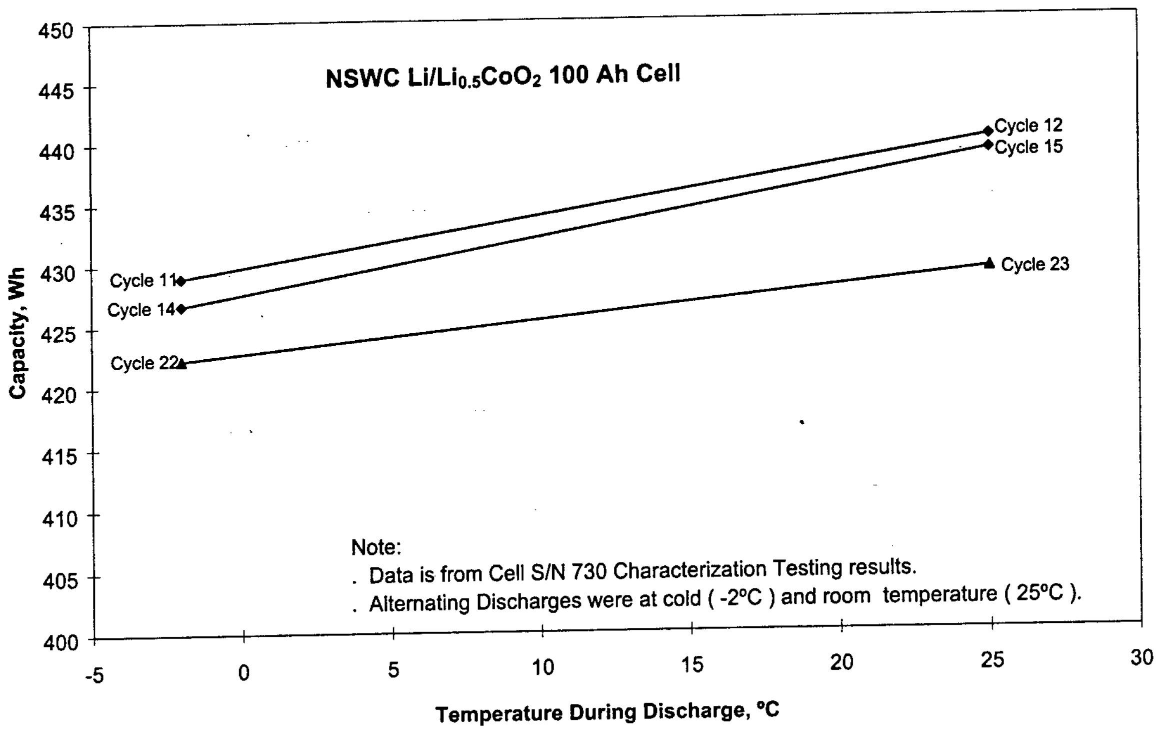


Figure 14. Cold Temperature Environment Effect on Capacity

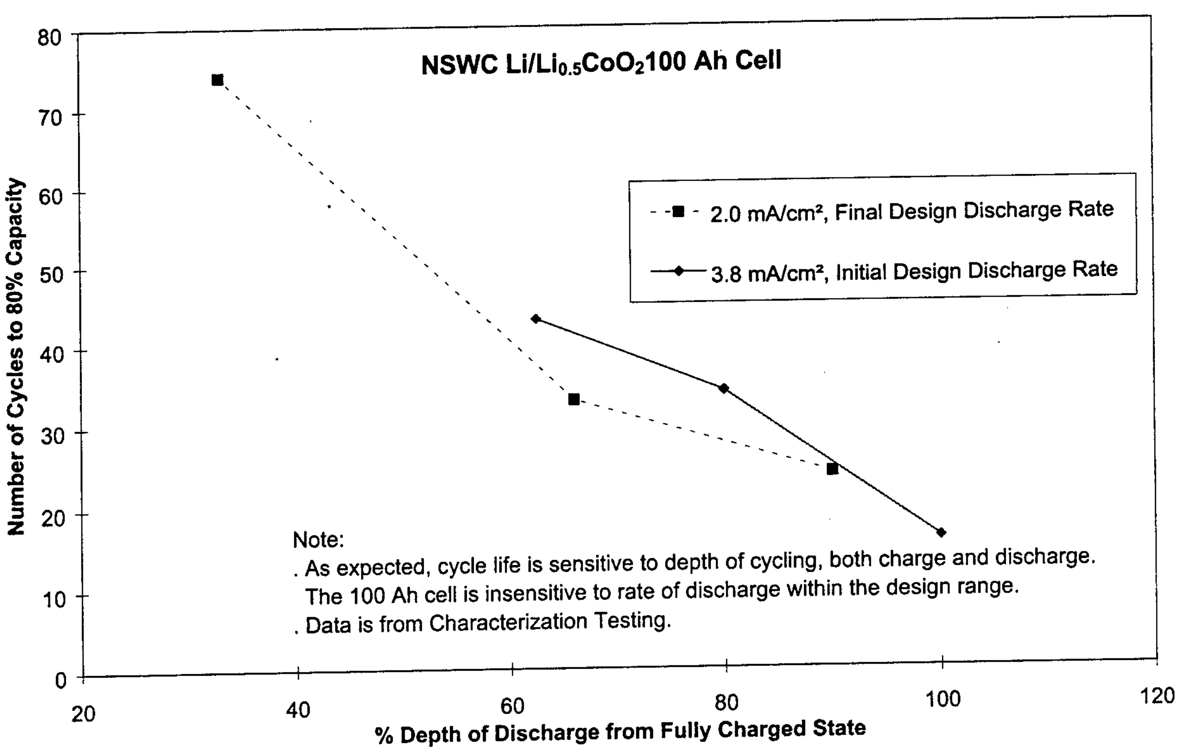
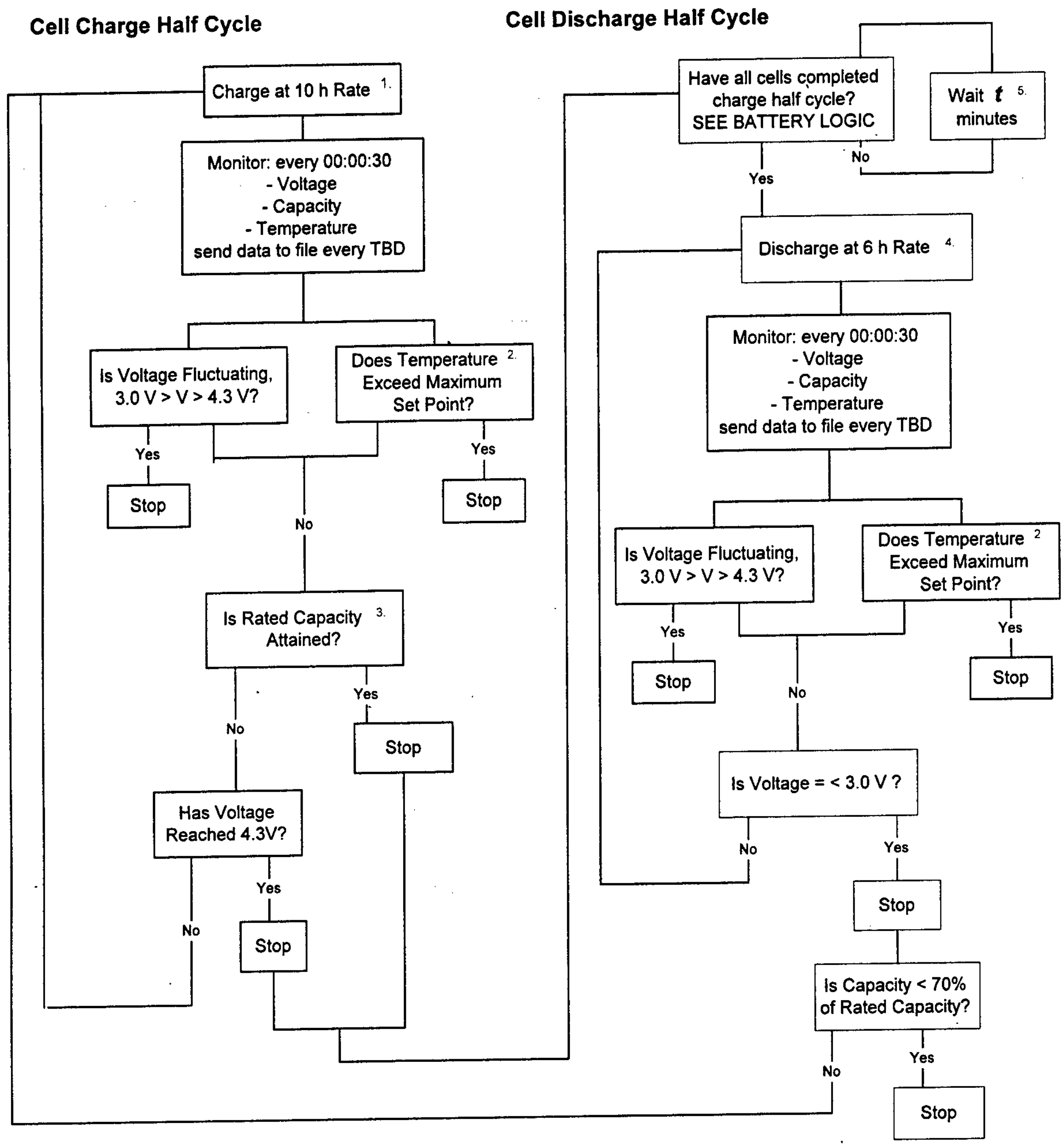


Figure 15. DoD Cycling Effects at Tactical Discharge Rates

5.0 SMART CHARGE CONTROL AND MONITORING AT THE CELL LEVEL

The 100 Ah cell was substantial enough to be a key building block for larger modules, but at the same time allow demonstration of series and parallel connected cells, key to any Underwater Vehicle propulsion system. It was the management of numerous cells in series/parallel arrangement, and the complexity of charge control in that situation that led the Navy to modify the existing contract and point the remaining resources toward a demonstration with safety and efficient operation as its goals. The effort to accomplish these goals first required a definition of the logic for control. Logic was added for discharge as well as charge since both processes have safety concerns. Electrical currents in both cases are high enough to produce rapid heating at any fault point created in the battery. It was also a key design parameter to create all of the control and monitoring functions as individual logic for each cell as a stand-alone device. This requirement then necessitated that the electronic control be board mountable and be restricted in size to that of the individual cell it is controlling. At the same time each individual cell must work homogeneously within the battery complex, allowing any one or more cells to be bypassed if necessary without affecting the load levels on the remaining functioning cells. Logic diagram for cell charge and discharge are presented in Figure 16. A logic diagram at the battery level is shown in Figure 17.

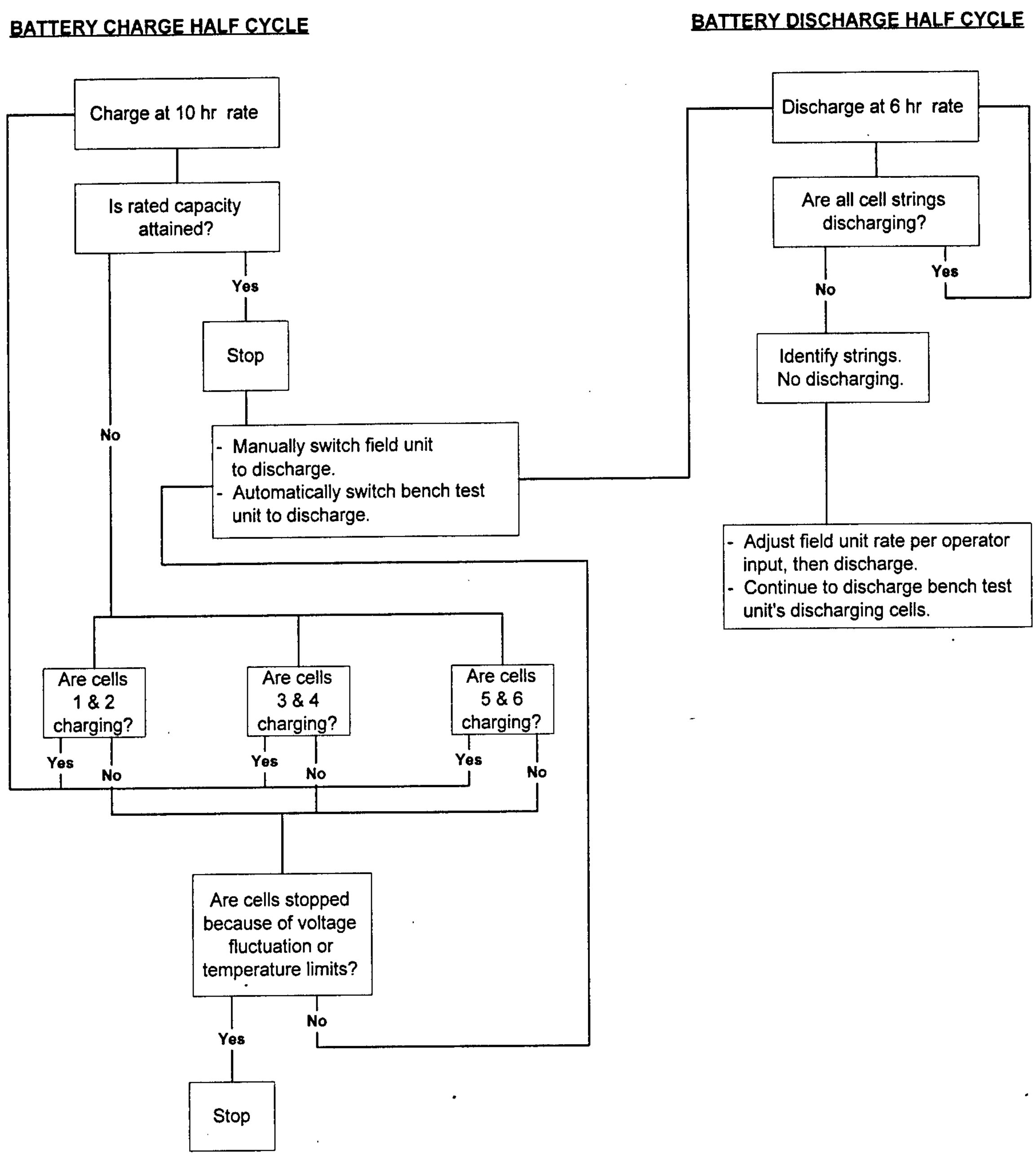


Notes:

1. 10 hour charge rate is 12 amperes (adjustable ± 2 amp).
2. Maximum set point temperature is 50°C.
3. Rated capacity is 110 Ah (adjustable ± 5 Ah).
4. 6 hour discharge rate is 18.6 amperes (adjustable ± 2 amp).
5. Wait time, *t* is 1 minute.

[B70512-4.vsd]*paw

Figure 16. Charge/Discharge Logic for Each Cell of the 300 Ah Smart Battery



[B70520-1.vsd]

Figure 17. Charge/Discharge Logic for Battery Overview of the 300 Ah Smart Battery

5.1 The Smart Battery Product

The firmware, the software, and the hardware were all created by DaTran Corporation, Tulsa, Oklahoma. The initial checkout was performed at DaTran followed by installation on the cells and battery at Alliant. Although the purpose of the contract was not to demonstrate portability, however, efforts to control the size of the printed circuit board were largely successful and the fact that the Smart Battery System (SMB) is PC-based would allow future field demonstration with minor "ruggedization" added. Following is a product description.

Product Description

Alliant's SMB system is an integrated smart battery charger system. The SMB controller system consists of six SBI battery charger boards and a host PC that is running the Alliant SBI Program. The host PC communicates with each SBI board through an I2C (pronounced eye squared see) interface and a multiplexed RS232 interface. There is a SBI board on each battery cell.

The Alliant SBI Program provides the user with an easy to use comprehensive interface to the entire battery system. It allows the user to set the various set points, then control and monitor the charge and discharge cycles of the battery system and it periodically logs the condition of each cell. The period is user definable from 1 second to 999 minutes. The data in the log file consists of date, time, voltage, current, temperature, and capacity for each cell. This data can be imported into a spreadsheet program such as Microsoft Excel for analysis.

The SBI board is a microcontroller controlled battery charger circuit board. The microcontroller used for the SBI board is a derivative of the 80C51--microcontroller family that either contains internal flash memory (ATMEL AT89C55), or internal EPROM (Philips P87C58EBLKA). The SBI board has an EEPROM (Microchip 93AA66) for storing non-volatile information. Each SBI board is given charge or discharge parameters by the Alliant SBI Program, and controls the charge and discharge of its cell. The SBI board reads voltage, current, and temperature. It sends this information to the Alliant SBI Program as requested.

The multiplexed RS232 interface is used for all communications between the Alliant SBI Program and the SBI boards except for voltage, current and temperature readings. It is the primary interface between the Alliant SBI Program and the SMB. The RS232 multiplexer has a standard DB9P connector to connect to the PC and six SBI interface cables to connect to each SBI board. The RS232 multiplexer also has a DC power adapter that must be plugged in to operate.

The SBI boards need two external 12 V DC power supplies to charge. The three boards that have the positive posts tied together share one of the power supplies and the three boards that have the negative posts tied together share the other power supply.

SMB Screen Displays

Once the SMB program is installed on a PC with Windows 95™ or higher, a series of screen displays allows the technician to review the status of each cell in the battery and set or change points. The screen displays are listed in order of their normal appearance and usual sequence of operation.

- **Main Menu** - allows access to all features of the SMB. See Figure 18.
- **Data Logging Screen** - sampling rate of recorded data, if option selected, is numerically set for frequency in seconds or minutes. See Figure 19 and Notepad record sample, Figure 20.
- **Set Points Screen** - either global or individual cell option, to set temperature limits, voltage limits for charge and discharge, trickle charge current, charging current with limits settings. See Figure 21.
- **Monitor Cells Screen** - displays all cells in the battery by serial number and provides real time information on cell voltage, temperature, current, capacity, and state of activity (charging, discharging, idle, or alarm). See Figure 22.
- **Debug/Administrative Utilities** - displays system options, such as:

  initialize new cell

  set addresses and calibration

  access to memory

  requests for accumulation dump

  reset alarm

  terminal window

  See Figure 23 for a graphic of this screen.

Figure 18. SMB Main Menu

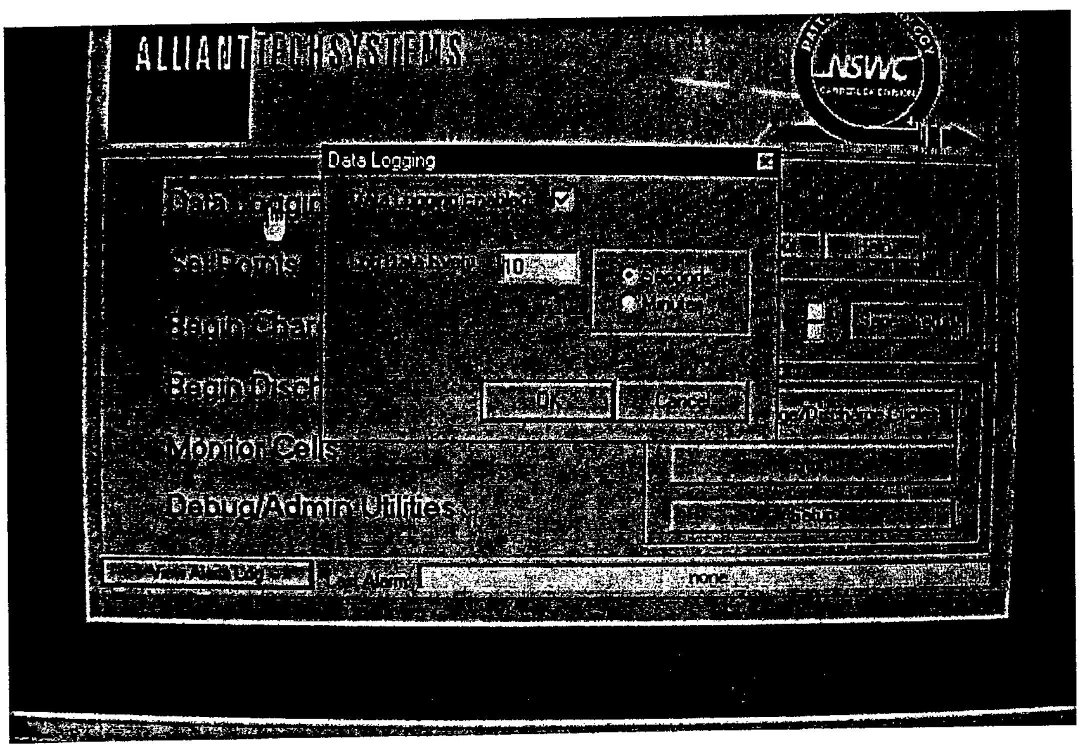


Figure 19. SMB Data Logging Selection Screen

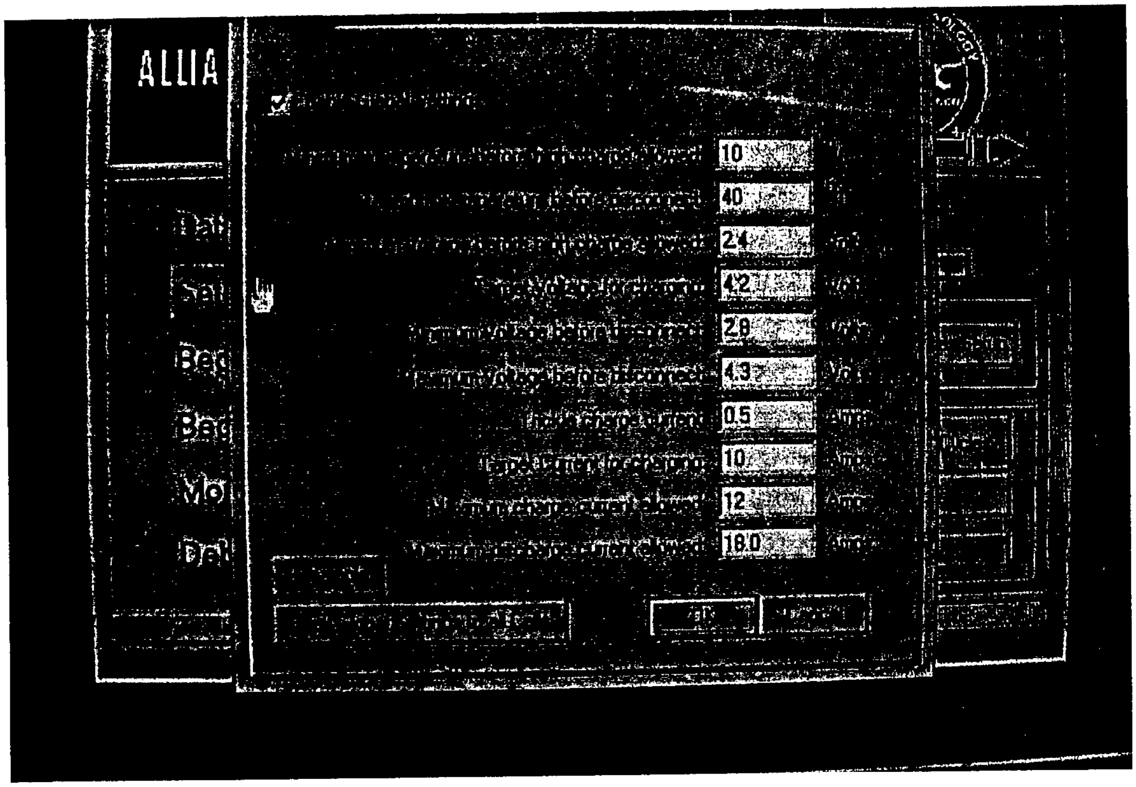


Figure 20. SMB Setup Screen

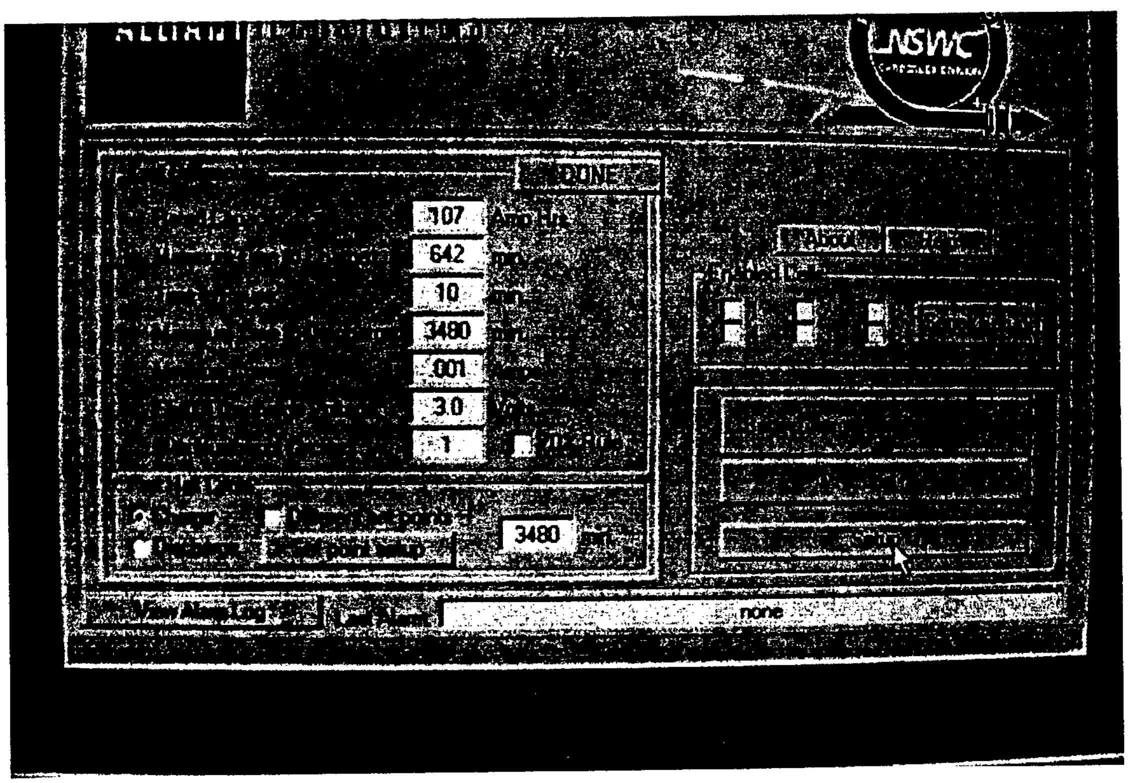


Figure 21. SMB Set Points Screen

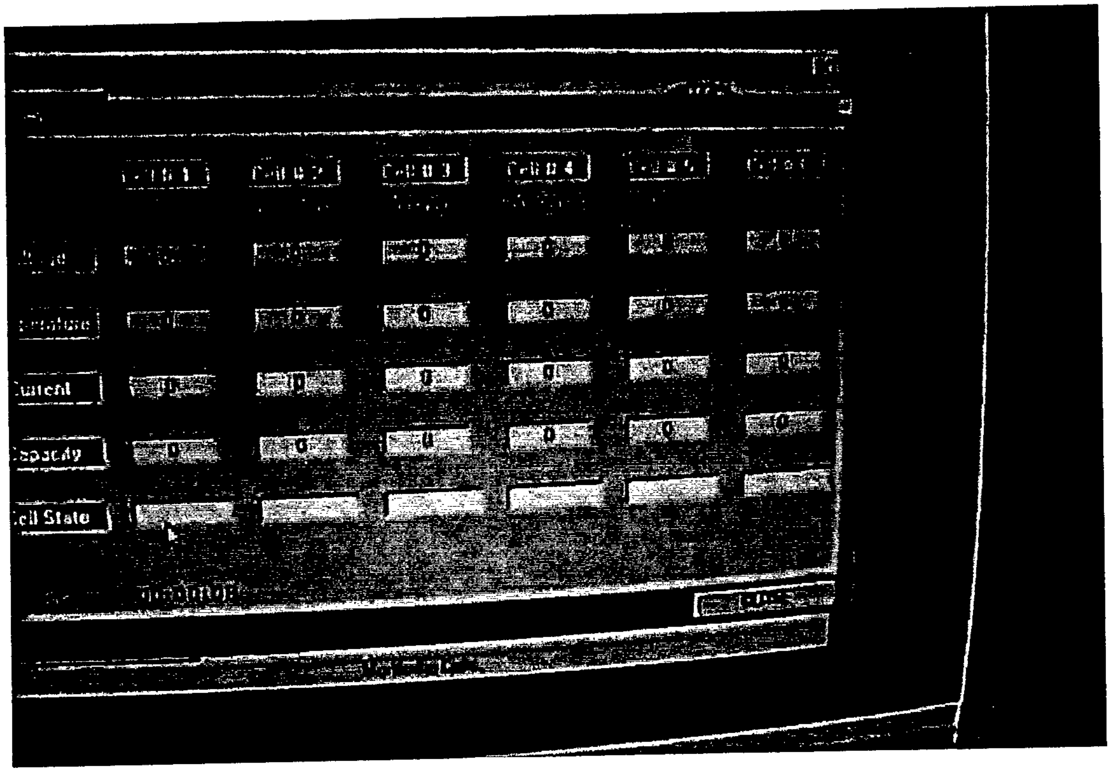


Figure 22. SMB Cell Monitoring Screen

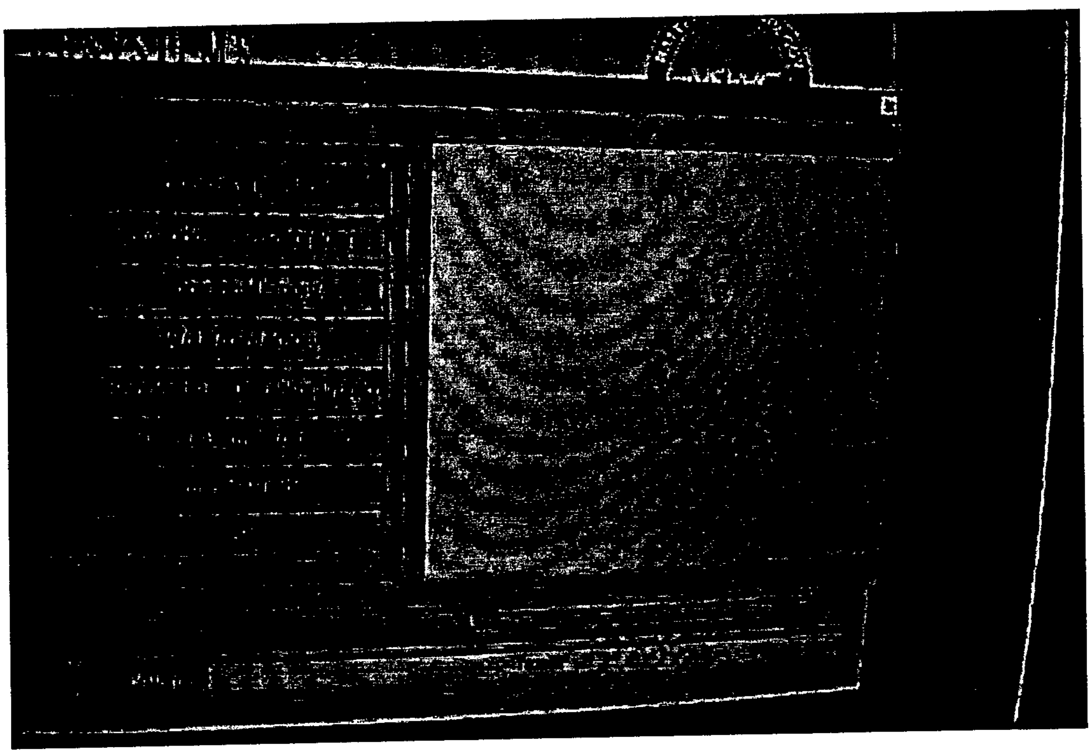


Figure 23. SMB Debug/Administrative Utilities Screen

5.2 Set Up of Smart Battery Demonstration

In parallel effort to that of DaTran Corporation designing and building the Smart Battery firmware, software, and hardware, the 300 Ah demonstration battery was being fabricated at Alliant Techsystems. Once the six individual 100 Ah cells were constructed, the battery was made by connecting them in a series/parallel arrangement to form a 300 Ah, 8.0 V system. The sketch in Figure 24 depicts the general arrangement, plan view of two of the six cells.

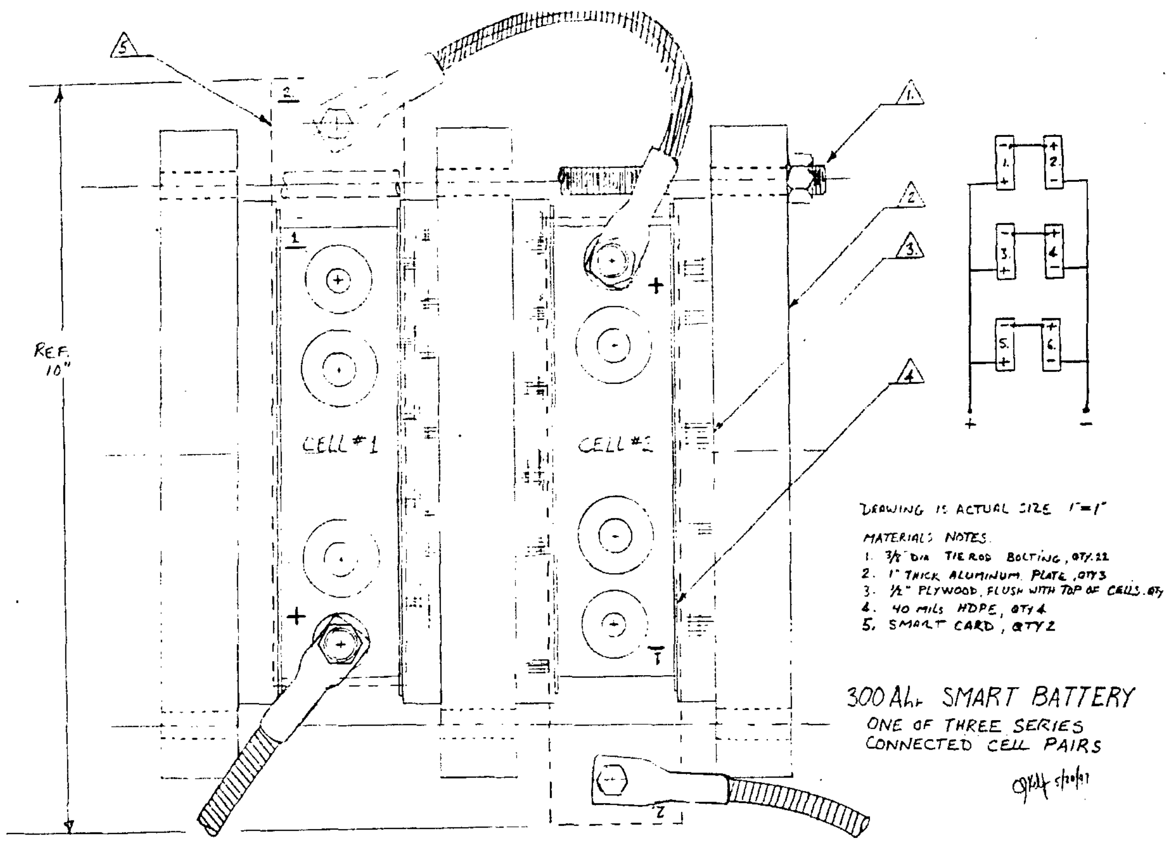


Figure 24. General Arrangement of Two Cells of the Six Cell Battery (Plan View)

As a general precaution, the battery was set up in the Special Test Laboratory, which has provisions for test room air cleaning and battery containment. The battery was placed in a chamber that allowed environmental control for cold (-2°C) and hot (+55°C) testing. A number of photographs were taken of the complete Smart Battery test assembly and are shown as a matrix of Figures 25 through 33.

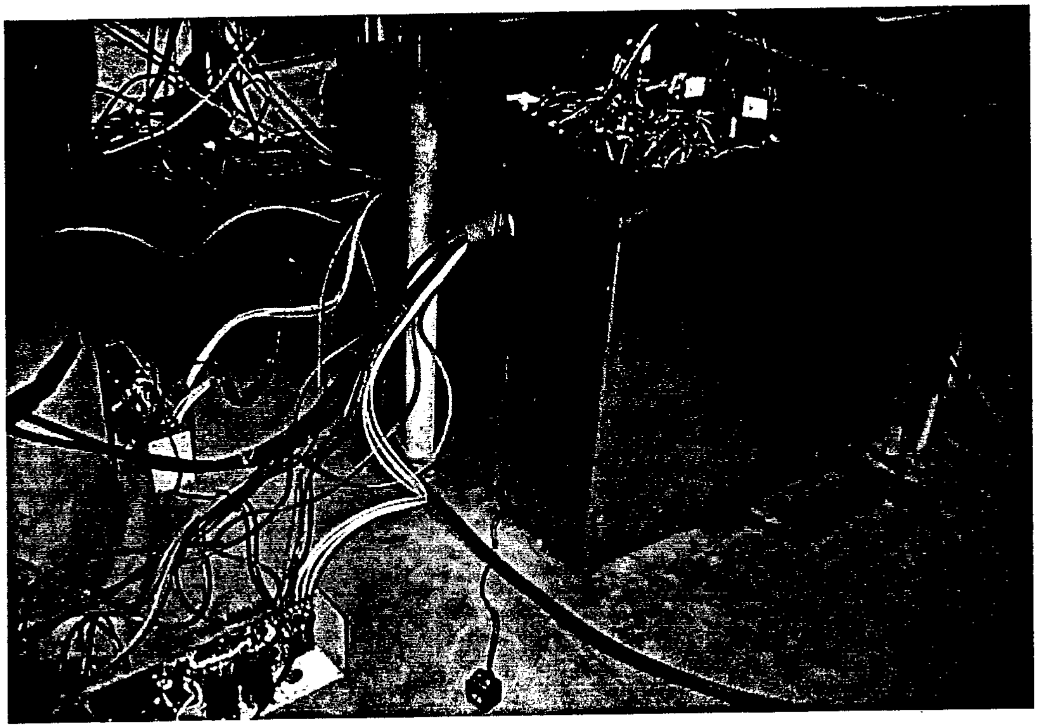


Figure 25. Test Chamber

Figure 26. The SMB Battery

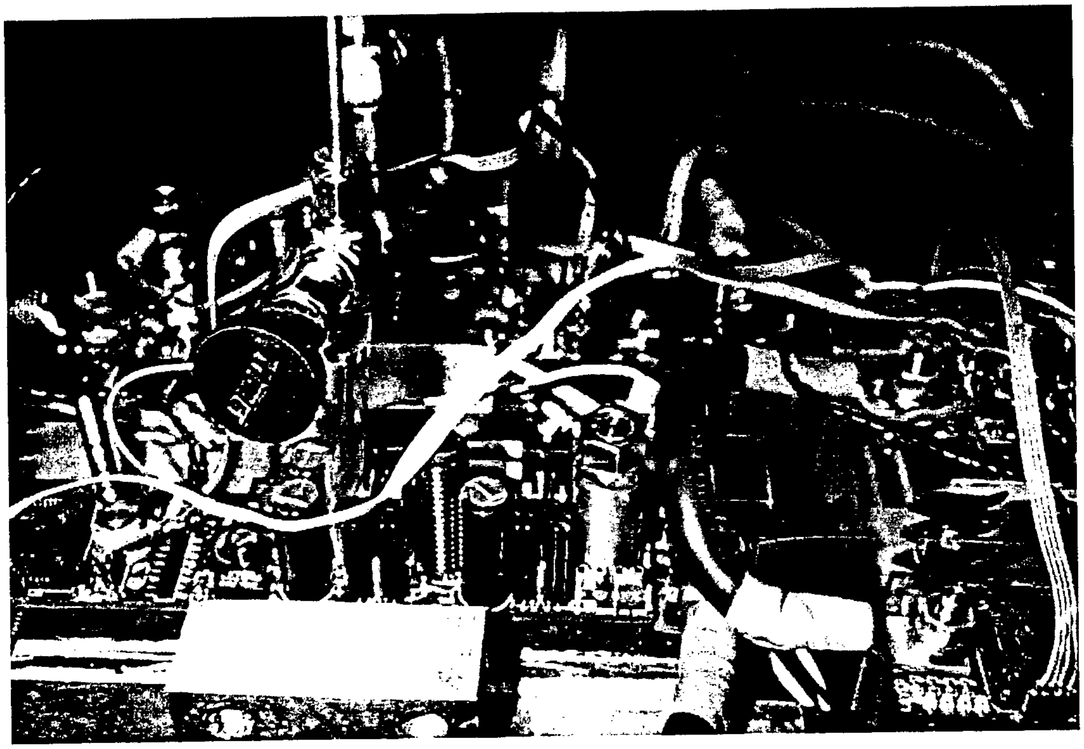


Figure 27. Close-up of PCB's

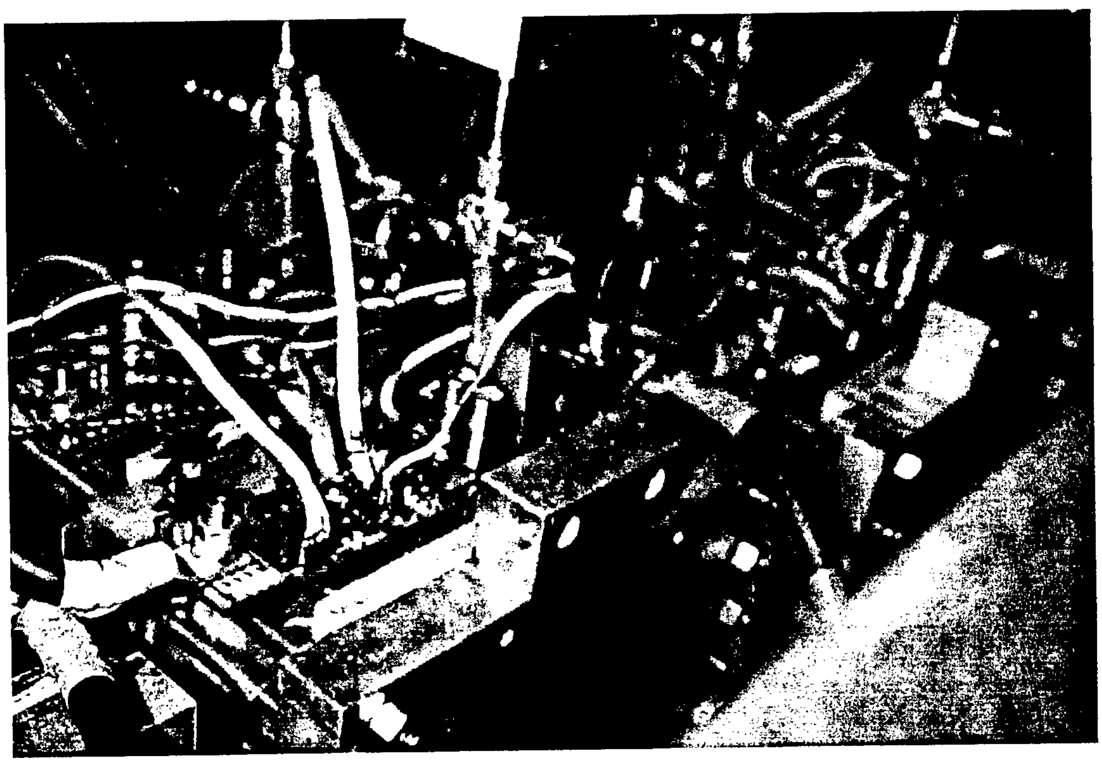


Figure 28. Side View of SMB Battery

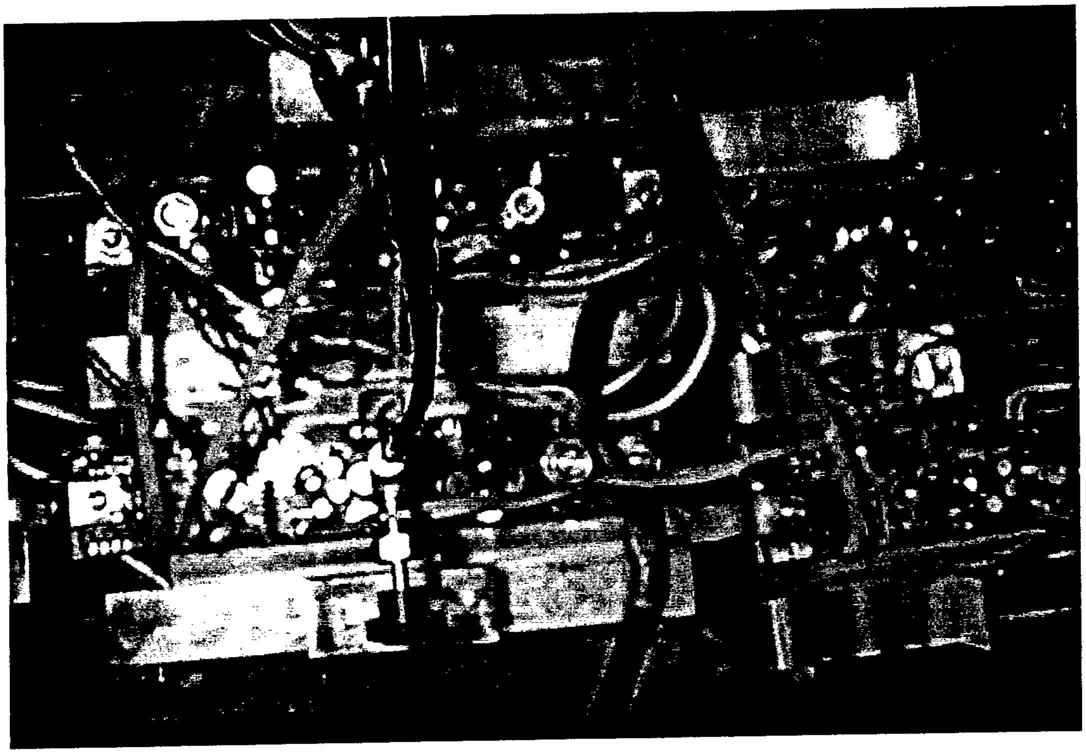


Figure 29. SMB Module Looking Down

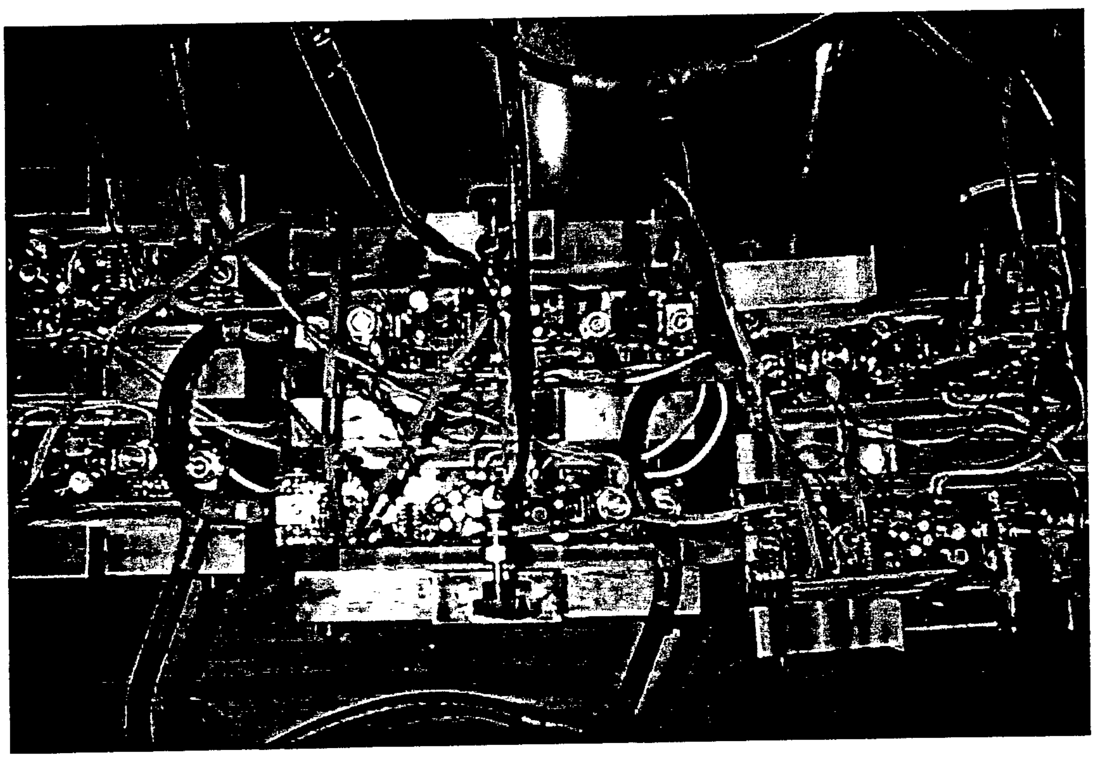


Figure 30. SMB Battery Looking Down

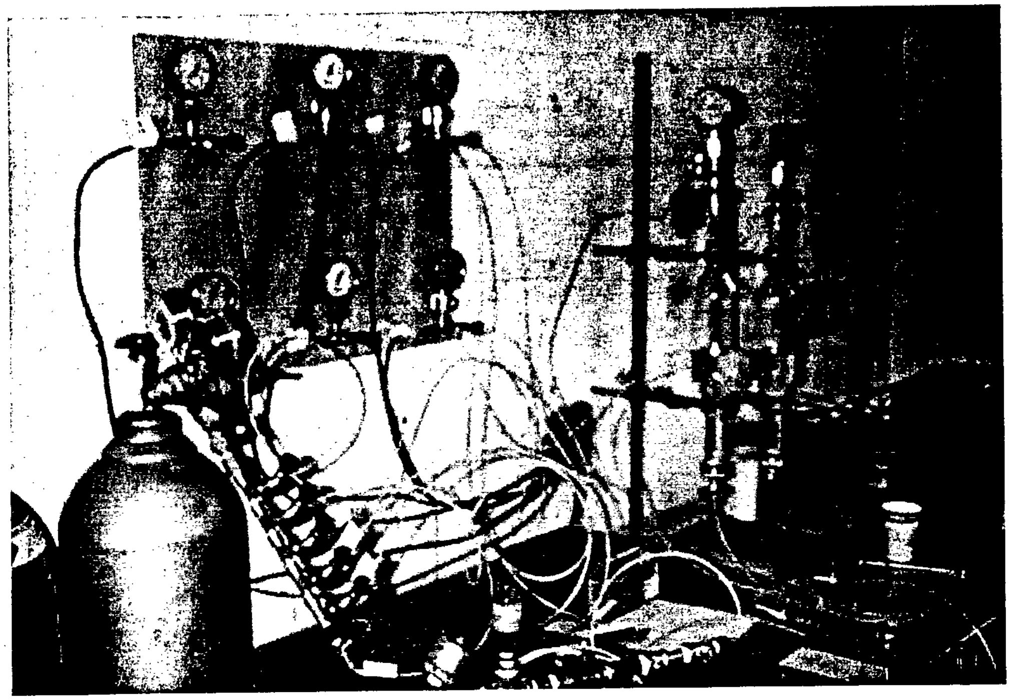


Figure 31. Remote Electrolyte Fill Station

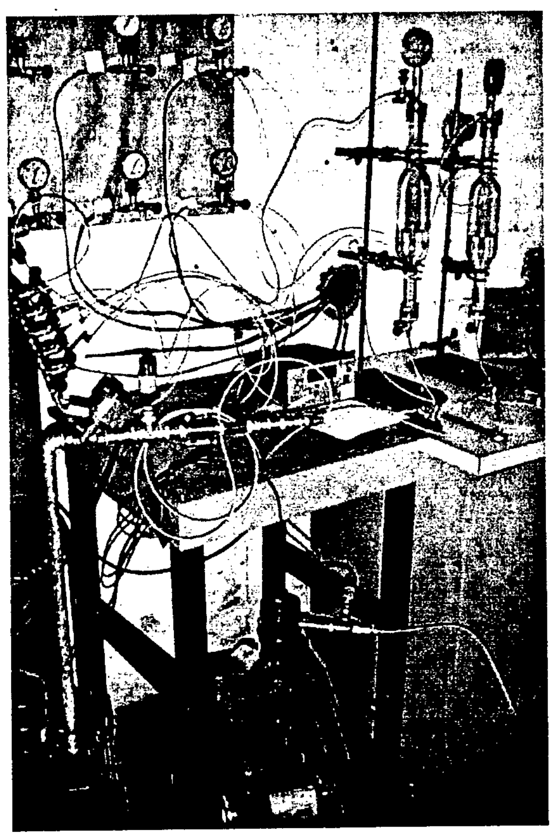


Figure 32. Calibrated Electrolyte Fill Reservoirs

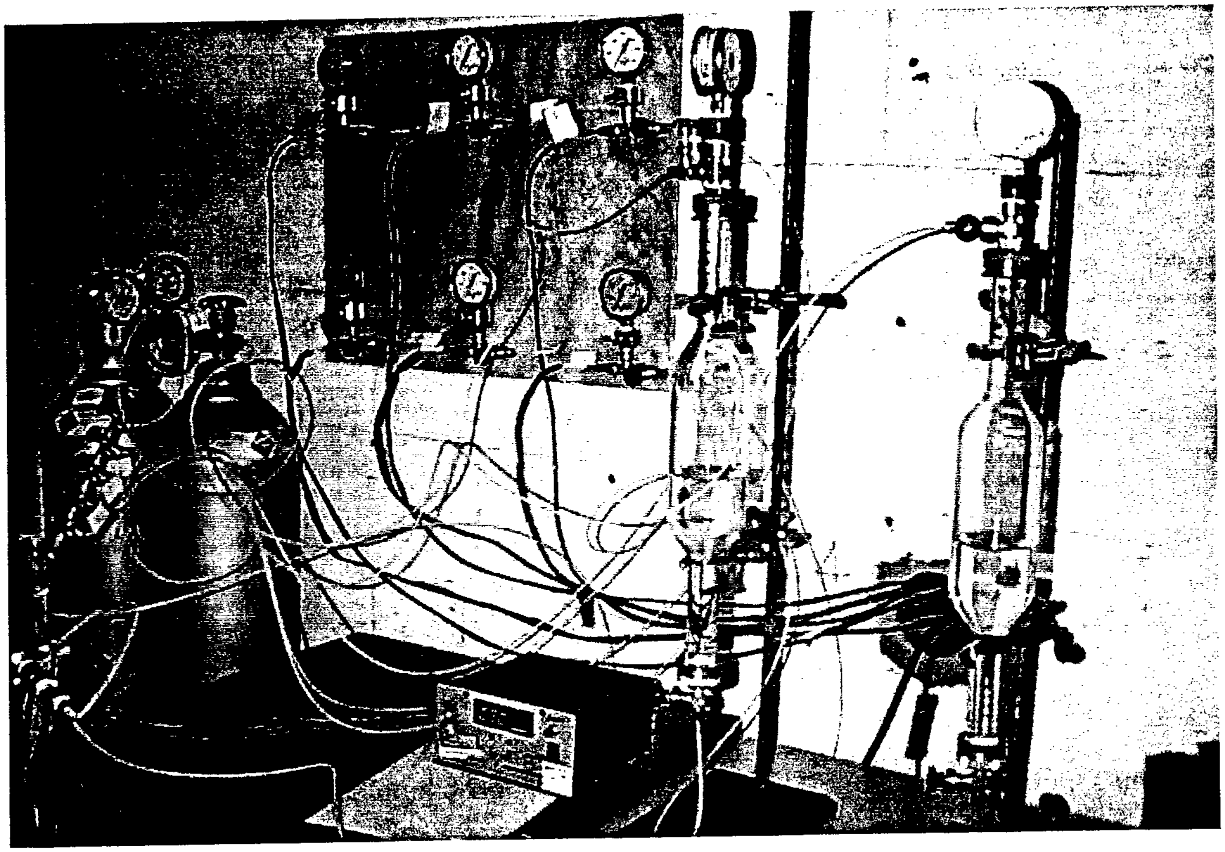


Figure 33. Pressure Gauge Bank for CO_2 Charge

5.3 300 Ah, 8.0 Volt Smart Battery Function Test Results

The cells in the battery assembly were not filled with electrolyte until the test setup was completely ready. Normal procedure required a vacuum draw down of each cell and then electrolyte filling with a known volume, usually 80% of total void volume. In this case, each series pair of cells was filled with electrolyte simultaneously. The reason for this was that electrolyte filling is backed with 60-psig carbon dioxide gas. Case swelling can occur. In order to maintain a balanced state between each pair of cells they were activated together. It should also be mentioned that the fixture for each pair of cells allowed pressure transfer between them. Please refer to the sketch of Figure 25 for positioning of fixtured plates. Also within the battery fixturing, plywood plates on either side of each cell acted as insulators. Since each cell was being monitored independently for temperature, thermal separation was necessary. Smart Battery use in field applications is not anticipated to need the type of fixturing described above. Cell separation by metal plate and wooden planks was for the purpose of cell and battery characterization. The high expansion forces described in Section 3.3 can be compensated in normal battery tray design without the need for fixture plates.

<u>Smart Battery Charge</u>

The first Smart Battery Charge began on December 9, 1998 with a low current constant voltage step, followed by a fast rate (10 A) constant current charge. As part of the Smart Battery design package, DaTran Corporation included a plotting routine that allowed graphic representation of

the monitored parameters, i.e., voltage, capacity, temperature, and current. Figures 34 through 43 depict capacity increase of each cell in the battery over the first charge. Once individual cells reached a fully charged state, i.e., 106 Ahs, they were automatically switched to idle and current for that cell was reduced to zero while other cells remained in a constant state of charge at 10 amperes each without fluctuation.

6.0 CONCLUSIONS

The primary goal of the program was accomplished, namely, to demonstrate the lithium/lithium cobalt oxide rechargeable battery system may be further considered for use in the SEAL Delivery Vehicle. An energy density of 100 Wh/lb through 50 cycles at 100% depth of discharge was nearly accomplished. We reached a level of 80 Wh/lb (hard packaged) and 25 cycles minimum, 40 cycles maximum of 100% depth of discharge. For the first time, the physical constraint requirements of this advanced pressurized system were defined. Characterization of the 100 Ah $Li/Li_{0.5}CoO_2$ cell through a build and test of 30 hermetically sealed cells generated information necessary to design batteries for the SDV application as well as other types of vehicles or any applications in need of a high voltage system, high energy capacity system. By far the greatest advancement of this program work was the integration of a series/parallel connected battery with full electronic control by a small cell top mounted circuit. In addition to the safety benefit provided by the control mode of the Smart Battery electronics, the monitoring mode gives the user immediate information on battery status at the individual cell level. The monitoring mode can also archive information to provide battery and cell history, allowing the user to make decisions on cell exchange or charging prior to releasing a battery for vehicle installation.

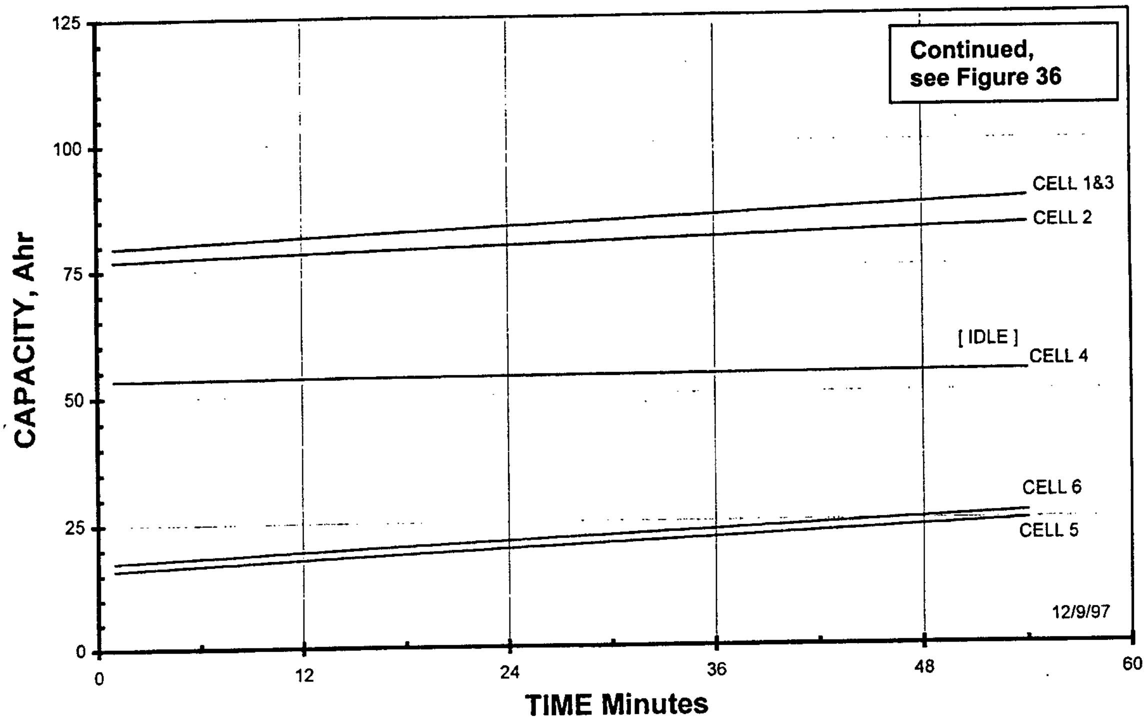


Figure 34. Charge of Unbalanced Cells, Constant Voltage at 10 Ampere

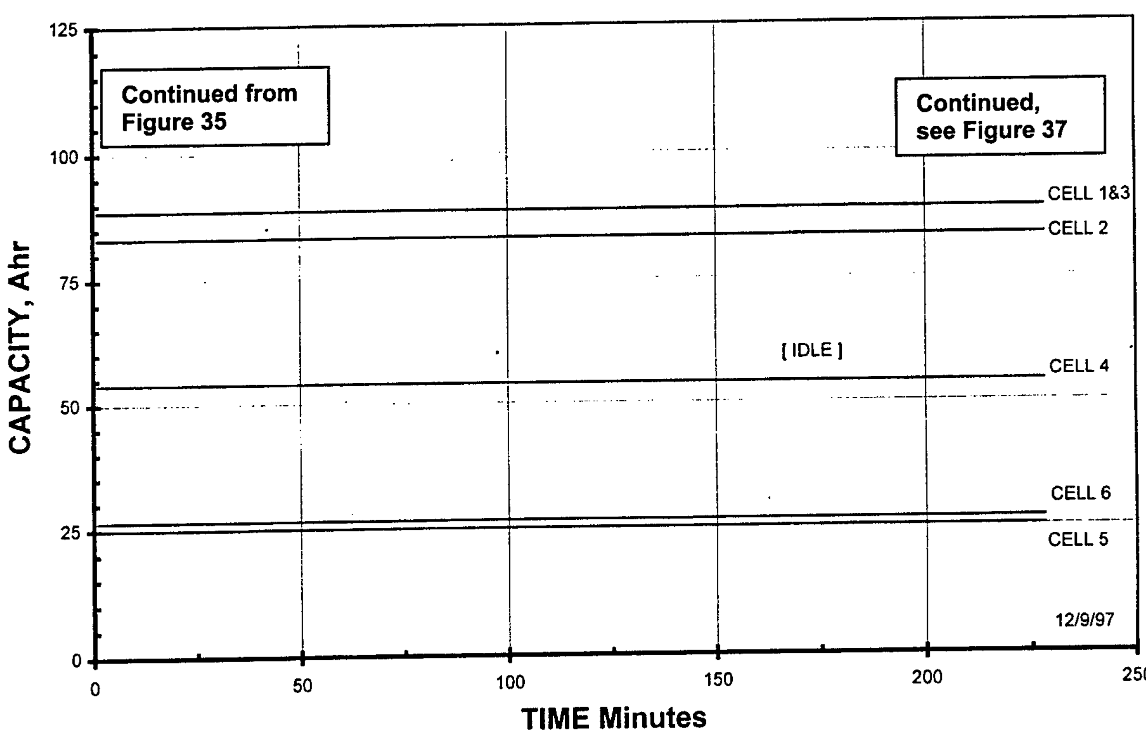


Figure 35. Charge of Unbalanced Cells, Constant Voltage at 10 Ampere (5 Amps Per Cell)

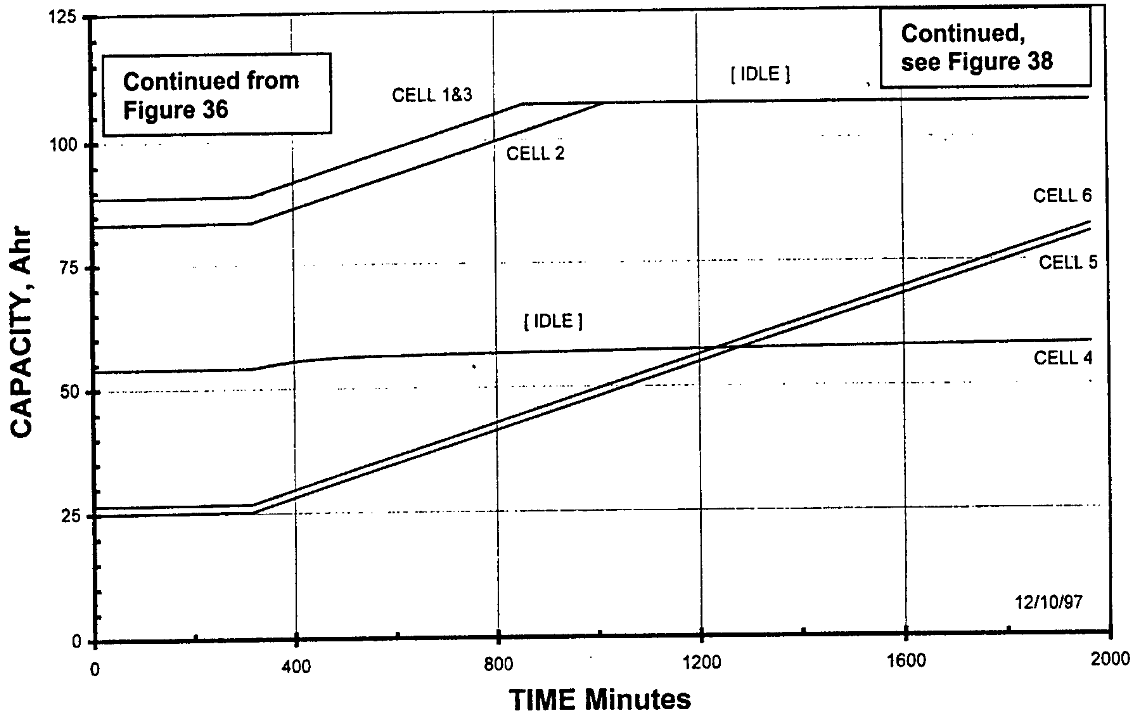


Figure 36. Charge of Unbalanced Cells, Constant Voltage Charged to Constant Current (2 Amps Per Cell)

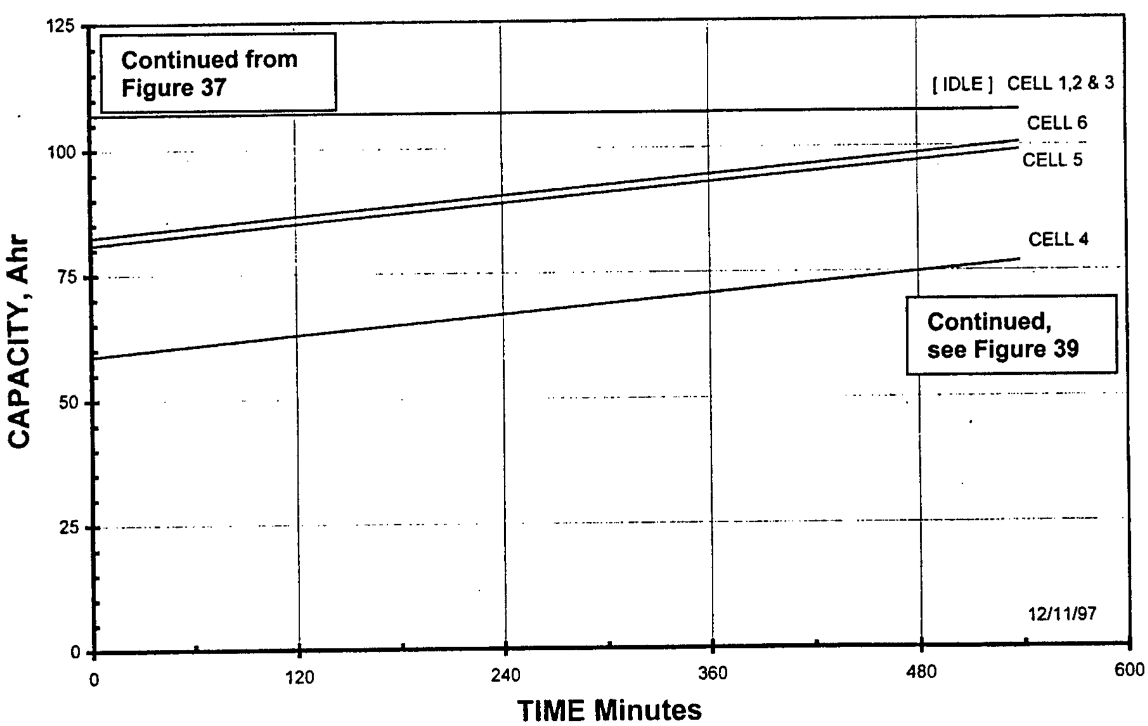


Figure 37. Continued Charge of Unbalanced Cells, Constant Current of 2 Amperes Per Cell

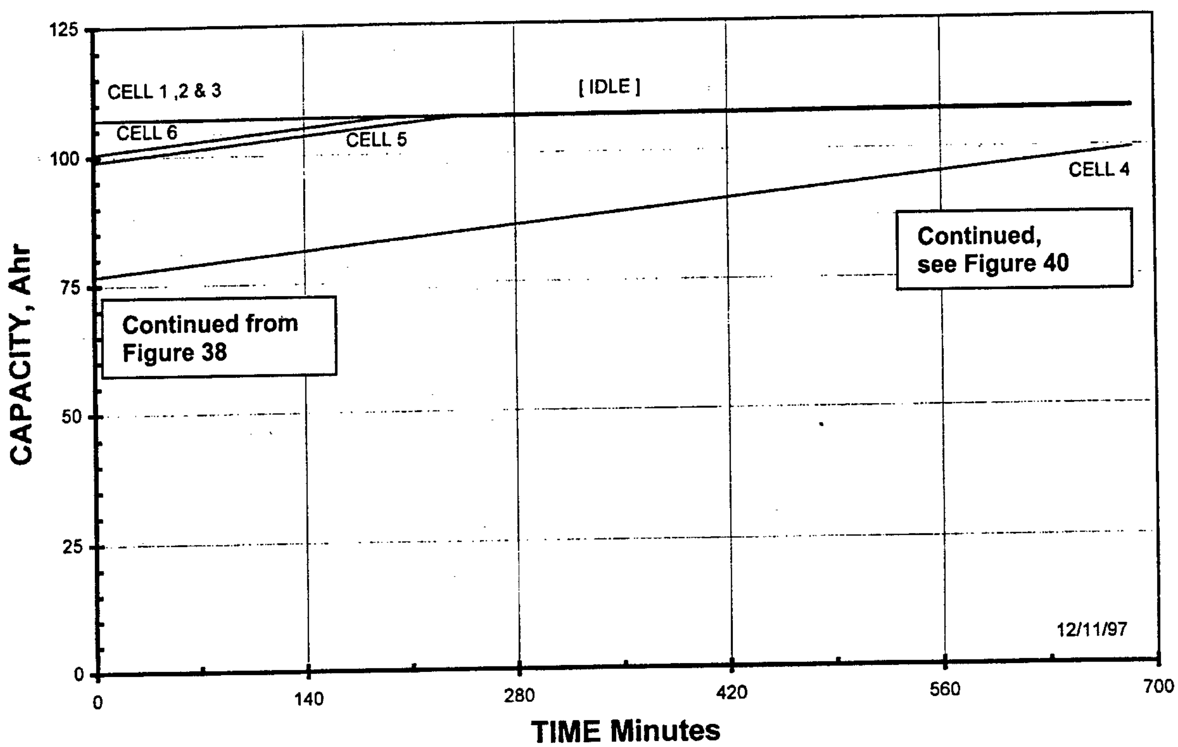


Figure 38. Continuous Charge of Unbalanced Cells, Constant Current of 2 Amperes Per Cell

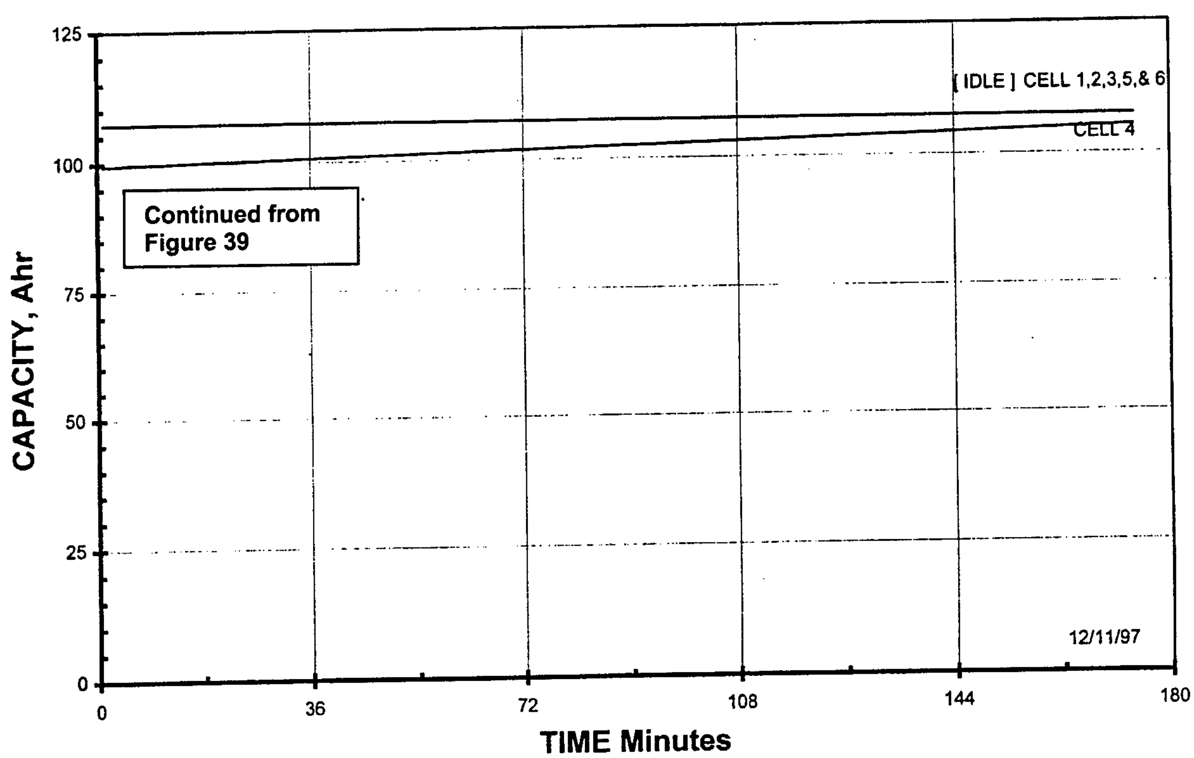


Figure 39. Continued Charge of Unbalanced Battery, Constant Current

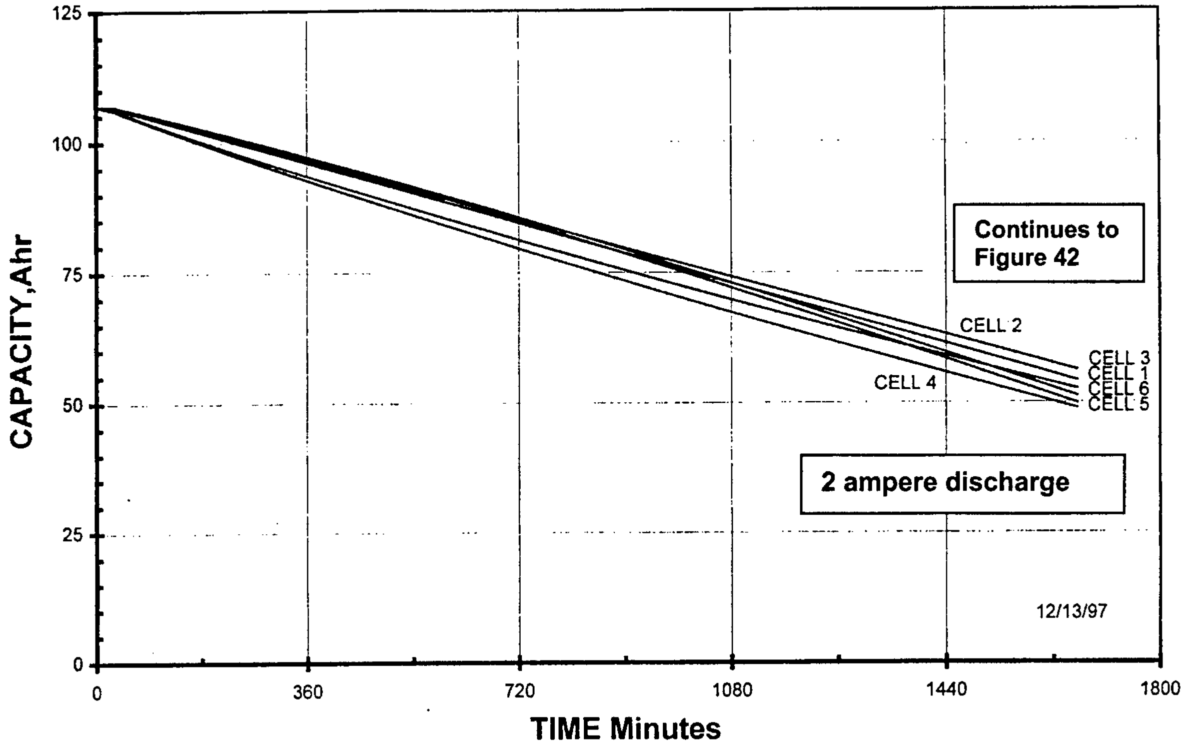


Figure 40. Discharge of Balanced Battery Initiated After 100% Charge

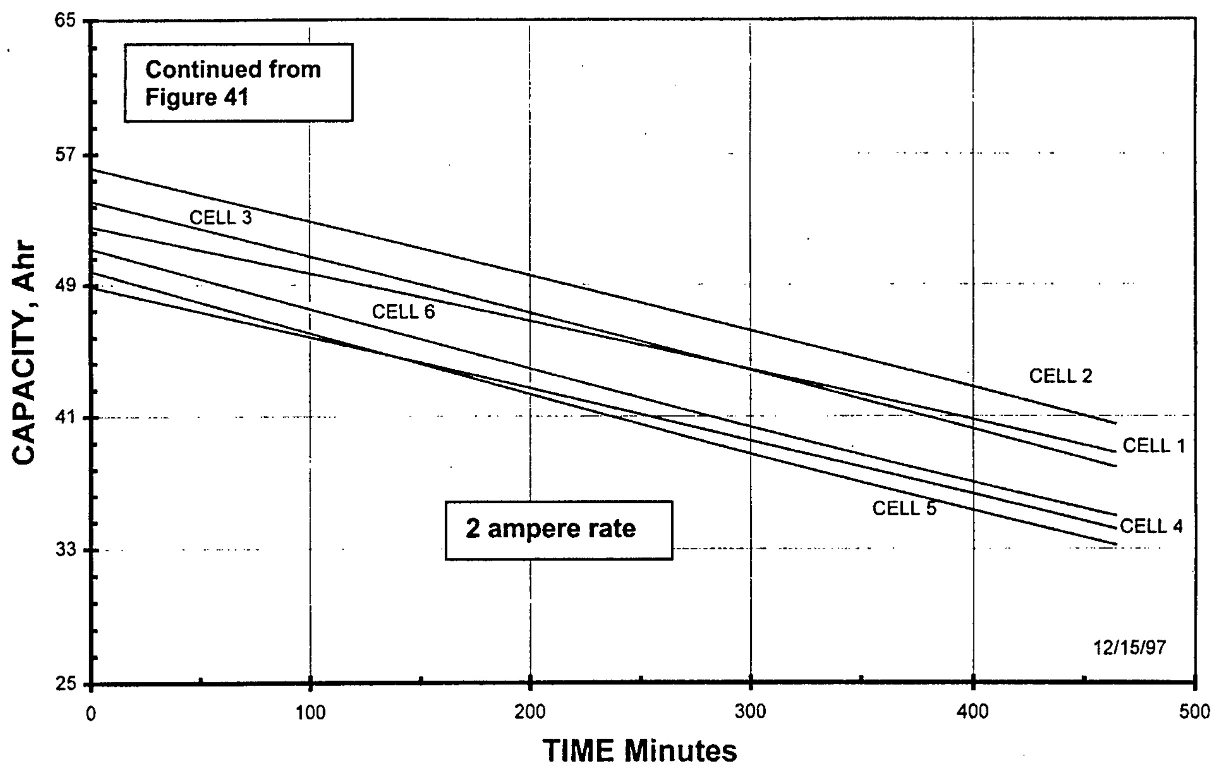


Figure 41. Discharge of Balanced Battery Initiated After 100% Charge (cont)

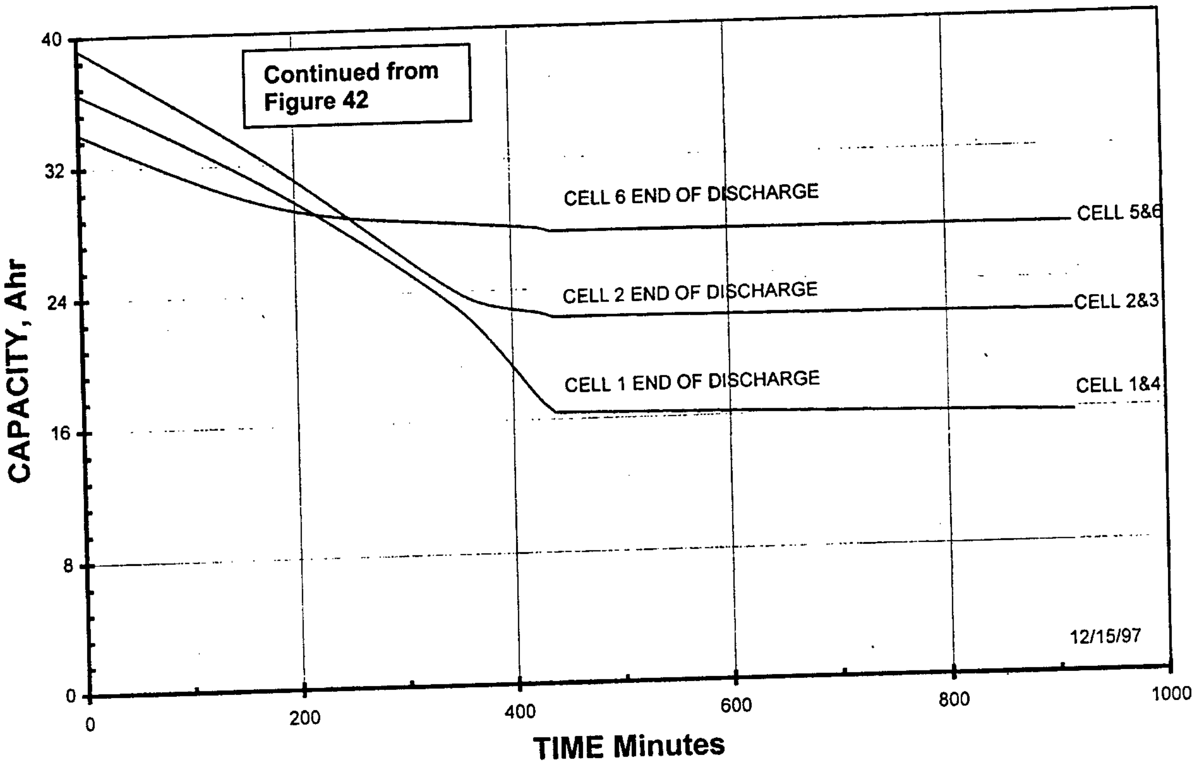


Figure 42. Discharge of Balanced Battery Initiated After 100% Charge (cont)

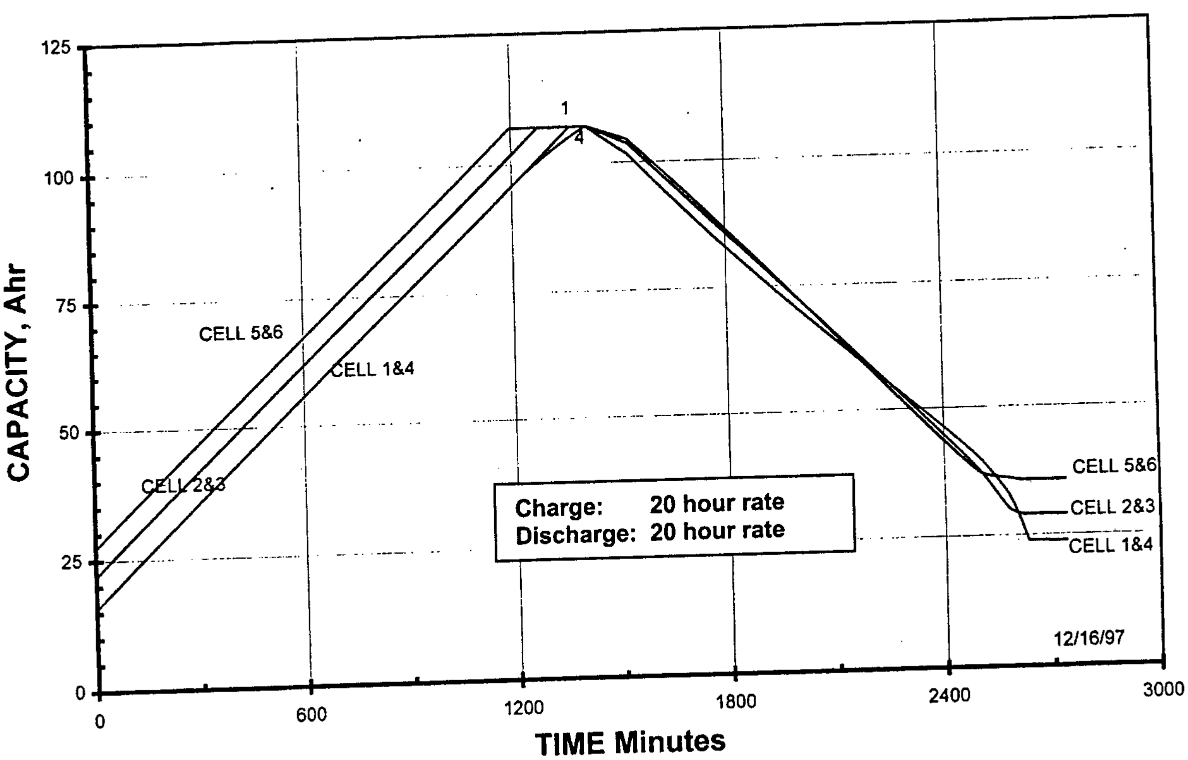


Figure 43. Charge at 20 Hour Rate and Discharge at 20 Hour Rate

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APPENDIX A

100 Ah $Li_{0.5}CoO_2$ Cell Test Results

FLAT PLATE FP509													ACTIVATED: 3/8/96
	CHARGE					DISCHARGE (C/6)							
CYCLE #	RATE	CUTOFF VOLT.	AMP-HRS	TEMP.(°F)	PRESSURE (PSIG)	AMP-HRS	% RETURNS	AC IMPED. (mΩ)	TEMP.(°F)	PRESSURE (PSIG)	FORCE GAUGE	PLATEAU VOLT.	REMARKS
1	C/20	4.079	9.93	RT	-	9.701	97.69	-	RT	-		3.88	
2	C/20	4.099	9.93	RT	-	10.085	101.56	-	RT	-		-	
3	C/20	4.099	9.93	RT	47	10.068	101.39	-	RT	-		-	
4	C/20	4.098	9.93	RT	-	10.052	101.23	-	RT	-		3.88	
5	C/20	4.098	9.93	RT	-	9.979	100.49	-	RT	-		-	
6	C/20	4.102	9.93	RT	-	9.897	99.67	-	RT	-		3.88	
7	C/10	4.119	9.93	RT	49	9.49	95.57	-	RT	-		-	
8	C/10	4.128	9.93	RT	-	9.852	99.21	-	RT	-		-	
9	C/10	4.123	9.93	RT	-	9.724	97.93	-	RT	48		3.88	
10	C/10	4.128	9.93	RT	-	9.775	98.44	-	RT	-		3.87	
11	C/10	4.133	9.93	RT	-	9.78	98.49	-	RT	-		-	
12	C/10	4.142	9.93	RT	-	9.79	98.59	-	RT	48		-	
13	C/10	4.151	9.93	RT	-	9.74	98.09	-	RT	-		3.87	
14	C/10	4.161	9.93	RT	-	9.72	97.89	-	RT	-		3.87	
15	C/10	4.177	9.93	RT	-	9.75	98.19	-	RT	-		3.87	
16	C/10	4.186	9.93	RT	-	9.72	97.89	-	RT	38		3.87	
17	C/10	4.195	9.93	RT	-	9.78	98.49	-	RT	-		3.87	
18	C/10	4.195	9.93	RT	-	9.77	98.39	-	RT	36		3.87	
19	C/10	4.194	9.93	RT	-	9.73	97.99	-	RT	36		3.87	
20	C/10	4.185	9.93	RT	-	9.45	95.17	-	RT	-		3.87	
21	C/10	4.206	9.93	RT	-	9.79	98.59	-	RT	36		3.87	
22	C/10	4.207	9.93	RT	-	9.814	98.83	-	RT	36		3.87	
23	C/10	4.207	9.93	RT	-	9.764	98.33	-	RT	-		3.87	
24	C/10	4.206	9.93	RT	-	9.765	98.34	-	RT	-		3.87	
25	C/10	4.208	9.93	RT	-	9.739	98.08	-	RT	-		3.87	
26	C/10	4.207	9.93	RT	-	9.725	97.94	-	RT	-		3.87	
27	C/10	4.207	9.93	RT	-	9.69	97.58	-	RT	-		3.87	
28	C/10	4.209	9.93	RT	-	9.719	97.88	-	RT	-		3.87	
29	C/10	4.214	9.93	RT	-	9.637	97.05	-	RT	-		3.87	
30	C/10	4.219	9.93	RT	-	9.636	97.04	-	RT	-		3.87	
31	C/10	4.22	9.93	RT	-	9.645	97.13	-	RT	-		3.87	
32	C/10	4.221	9.93	RT	-	9.584	96.52	-	RT	-		3.87	
33	C/10	4.228	9.93	RT	-	9.521	95.88	-	RT	-		3.87	
34	C/10	4.237	9.93	RT	-	9.464	95.31	-	RT	-		-	
35	C/10	4.246	9.93	RT	-	9.389	94.55	-	RT	-		-	
36	C/10	4.255	9.93	RT	-	9.3	93.66	-	RT	-		-	
37	C/10	4.217	9.93	RT	-	9.24	93.05	-	RT	-		-	
38	C/10	4.207	9.93	RT	-	8.1	81.57	-	RT	-		3.856	
39													
40													
41													
42													
43													
44													
45													
46													
47													
48													
49													LAST UPDATED: 04-08-96
50													

NSWC-FP510 Rated Capacity;Ahr.:12.29

CHARGE (10 hour rate, except as noted) — DISCHARGE (6 hour rate except as noted)

Activated 8/28/96

CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	RESSURE (PSIG)	DISCHAR RATE	OCV	AMP-HRS Sum all sp	RETURN %	PLATEAU VOLT.	REMARKS
1	20hr	4 0791		12 29	AMB		LR		12 1968	99 20	3 77	
2	10hr	4 0976		"	"		"		12 3144	100 20	3 75	
3	"	4 1014	4 05	"	"		"		12 304	100 10	3 73	
4	"	4 1056	4 08	"	"		"		12 254	99 70	3 7	
5	"	4 1089	4 08	"	"		"		12 205	99 30	3 69	
6	"	4 1118	4 09	"	"		"		12 256	99 70	3 69	
7	"	4 1106	4 08	"	"		"		12 323	100 30	3 76	
8	"	4 1086	"	"	"		"		12 267	99 80	3 71	
9	"	4 0999	"	"	"		"		12 255	99 70	3 71	5 day stand after 9th cycle.
10	"	4 1012	4 07	"	"		HR		7 398		0 7749	
11	20hr.	4.1036	4 07	7.396	"		10hr.		12 063	98 20	3 89	
12	"	4 1012	4 09	12.29	"		10hr.		12 279	99 90	3 85	
13	"	4 1036	"	"	"		10hr.		12 299	100.10	4	
14	"	4 1036	"	"	"		10hr		12 368	100 60	3.9	
15	"	4 1022	"	"	"		HR		8 45448			26W power step. File fp510c
16	"	4.1024	"	8.425	"		10hr		12.351	100 50		File fp510d
17	"	4 1088	4.08	12.29	"		HR		7 397			30W power step 54 min. runtime.2 day stand after this run.
18	"	4.3		10.867	"		10hr.		15 608		3 86	File fp510e
19	"	4 1066		12.29	"		HR		11 377	92 60		28W power step
20	"	4 1663	4.15	"	"		10hr.		13 29	108.00	3 97	
21	"	4.1058	4.09	"	"		HR		11.258	91.60	3 7	28W power step. 3 day stand after this run.
22	"	4 105	4.09	11.247	"		HR		11 28	91 80	3 7	28W power step File fp510g
23	"	4.1212	4.1	11 56	"		HR		11 283	91 80	3.7	28W power step File fp510h
24	"	4 124	4.11	11 282	"		HR		10 786	87 80	3 6	28W power step File fp510i
25	"	4 1252	4.11	10 786	"		HR		7.5936		3 5	28W power step. File fp510j
26	"	4 3	4 28	10 447	"		HR		14.579		3 9	28W power step. File fp510k
27	"	4.1794	4.16	12 29	"		HR		12 972	105.50	3 8	28W power step File fp510l
28	"	4.1795	4 17		"		HR		12 08	98.30	3 8	28W power step File fp510m. 3 day stand after this run.
29	"	4.1901	4 17		"		HR		13.004	105.80	3 8	28W power step. File fp510n
30	"	4.1563	4.14		"		HR		12 116	98 60	3 8	28W power step. File fp510n
31	"	4.1763	4.16		"		HR				3 9	28W power step. File fp510n
32	"			12.29	"		HR		12.417			28W power step. File fp510n
33	"			"	"		HR		12.416			28W power step. File fp510n
34	"	4.175		"	"		HR		12.383			28W power step. File fp510n
35	"			"	"		HR		12 411			28W power step. File fp510n
36	"	4.1759		"	"		HR		12.407			28W power step. File fp510n
37	"	4.1758		"	"		HR		13.212			28W power step. File fp510n
38	"	4.1107		"	"		HR		11.412			28W power step. File fp510n
39	"	5.1105		4.238	"		HR					28W power step. File fp510n. Cell vented on following charge.
40												
41												
42												
43												
44												
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47												
48												
49												

NSWC-602 - 100 AH AT 90% DOD W/ 2M DSMF — **ACTIVATED: 11/21/95**

	CHARGE (C/20)						DISCHARGE (C/6)							
CYCLE #	CUTOFF VOLTAGE	AMP-HRS	AC IMPED. (mΩ)	TEMP.(°F)	PRESSURE (PSIG)	END OCV CHARGE	AMP-HRS	% RETURNS	AC IMPED. (mΩ)	RETURN Whr.	PRESSURE (PSIG)	PLATEAU VOLT.	END OCV DISCH.	REMARKS
1	4.102	86.51	15	71	40	-	83.349	96.35	19	312.6	39	3.75	-	
2	4.141	86.51	15	71	n/a	-	86.649	100.16	19	322.3	-	3.72	-	
3	4.137	86.51	15	71	n/a	-	86.516	100.01	19	321.0	-	3.71	-	
4	4.134	86.51	15	71	n/a	-	86.439	99.92	19	319.8	-	3.7	-	
5	4.137	86.51	15	71	n/a	-	86.419	99.89	20	319.8	-	3.7	-	
6	4.141	86.51	15	71	50	-	86.241	99.69	20	319.1	50	3.7	-	
7	4.144	86.51	16	71	50	-	86.117	99.55	21	318.6	50	3.7	-	
8	4.147	86.51	16	71	50	-	86.028	99.44	21	318.3	50	3.7	-	
9	4.151	86.51	17	71	50	-	85.61	98.96	21	316.8	50	3.7	-	
10	4.155	86.51	18	72	60	-	85.62	98.97	22	316.8	54	3.7	-	
11	4.162	86.51	19	72	-	4.098	85.746	99.12	23	317.3	-	3.7	3.838	
12	4.167	86.51	19	72	-	4.102	85.658	99.02	23	316.9	-	3.7	3.837	
13	4.169	86.51	19	72	54	4.105	85.286	98.59	23	315.6	-	3.7	3.836	
14	4.175	86.51	19	72	-	4.111	85.109	98.38	23	314.9	-	3.7	3.836	
15	4.18	86.51	19	72	39	4.114	83.375	96.38	23	307.7	-	3.69	3.838	Bleed psig from 54 to 30
16	4.202	86.51	19	72	70	4.135	83.893	96.97	23	309.6	-	3.69	3.837	60 Psig on charge for 16 hrs
17	4.218	86.51	19	72	-	4.15	81.188	93.85	23	299.6	-	3.69	3.839	80 Psig on charge for 3 hrs,
18	4.249	86.51	20	72	-	4.18	80.953	93.58	23	297.9	-	3.68	3.824	then bleed down to 50 psig.
19	4.289	86.51	20	72	-	4.218	82.681	95.57	23	304.3	43	3.68	3.848	
20	4.3	84.46	21	72	-	4.227	80.74	93.33	23	297.1	45	3.68	3.848	
21	4.3	81.45	22	72	37	4.227	79.717	92.15	23	292.6	43	3.67	3.847	
22	4.3	80.34	22.5	72	35	4.225	79.418	91.80	23	289.1	33	3.64	3.845	
23	4.3	80.44	23	72	34	4.225	79.377	91.75	23	288.9	33	3.64	3.843	
24	4.3	80.6	23	72	33	4.225	79.247	91.60	23	288.5	33	3.64	3.841	
25	4.3	80.087	23	72	31	4.222	79.377	91.75	23	288.1	33	3.63	3.844	
26	4.3	80.607	23	72	31	4.221	78.19	90.38	24	283.0	33	3.62	3.838	
27	4.3	81.267	24	72	32	4.222	77.05	89.06	25	278.9	33	3.62	3.835	
28	4.3	81.15	24	72	32	4.222	75.05	86.75	26	270.9	33	3.61	3.8351	
29	4.3	80.535	24	72	35	4.222	72.708	84.05	26	261.7	34	3.6	3.833	
30	4.3	76.523	24	72	38	4.1957	64.34	74.37		0.0				END OF TEST
31										0.0				
32		0	80											
33		50	80											
34														
35														
36														
37														
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NSWC-603 - 100 AH AT 90% DOD W/ 2M DSMF

ACTIVATED: 12/27/95

CYCLE #	CHARGE (C/20) CUTOFF VOLTAGE MACCOR	CUTOFF VOLTAGE ACTUAL	AMP-HRS	AC IMPED. (mΩ)	TEMP (°F)	PRESSURE (PSIG)	END OCV CHARGE	DISCHARGE (C/6) AMP-HRS	% RETURNS	AC IMPED. (mΩ)	TEMP (°F)	PRESSURE (PSIG)	DELTA VOLTAGE	PLATEAU VOLT.	END OCV DISCH.	REMARKS
1	-	4.0817	95.83	3	65	30	4.065	91.54	95.52	3	66	46	-	3.86	3.8544	12/28/95
2	-	4.0989	95.83	3	65	-	4.083	95.91	100.08	3	66	-	-	3.86	3.8454	
3	-	4.0997	95.83	3	65	-	4.0826	94.44	98.55	3	66	-	-	3.86	3.839	
4	-	4.1069	95.83	4	65	-	4.0877	95.83	100.00	4	66	-	-	3.86	3.836	
5	-	4.1063	95.83	4	65	-	4.0874	95.77	99.94	4	66	-	-	3.855	3.836	1/2/96
6	-	4.1075	95.83	4	65	41	4.088	95.85	100.02	4	66	-	-	3.855	3.834	
7	-	4.1076	95.83	4	65	42	4.0879	95.9	100.07	4	66	-	-	3.85	3.83	
8	-	4.1069	95.83	4	65	45	4.0868	95.58	99.74	4	66	-	-	3.84	3.829	
9	-	4.1082	95.83	4	65	-	4.0878	95.51	99.67	4	66	-	-	3.835	3.829	
10	-	4.1097	95.83	4	65	-	4.0887	95.39	99.54	4	66	-	-	3.83	3.831	
11	-	4.1125	95.83	4	65	-	4.0905	95.18	99.30	4	66	-	-	3.827	3.834	
12	-	4.1169	95.83	4	65	49	4.0945	95.32	99.47	4	66	-	-	3.825	3.833	
13	-	4.1204	95.83	4	65	-	4.0979	95.27	99.42	5	66	-	-	3.825	3.827	
14	-	4.1245	95.83	4	65	50	4.1015	94.64	98.78	5	66	-	-	3.82	3.83	
15	-	4.1343	95.83	5	65	-	4.1099	91.27	95.24	6	66	49	-	3.81	3.834	
16	-	4.1775	95.83	5	65	50	4.1514	79.31	82.76	6	66	-	-	3.785	3.848	
17	-	4.2994	95.83	5	65	-	4.2994	76.31	79.63	6	66	50	-	3.76	3.858	Poor performance on 1-15-96 tookcell off
18	-	4.236	88.03	5	65	50	-	105.84	110.45	-	66	62	3.73	3.803	3.85	test at 8 am in the 14th hr of charge.
19	4.153	4.08	95.83	-	65	45	4.092	95.97	100.15	-	66	38	3.71	3.783	3.852	put cell back on test on 01-24-96 at 8
20	4.157	4.084	95.83	-	65	45	4.09	95.5	99.66	-	66	37	3.699	3.772	3.8522	am on the 18th cycle in discharge.
21	4.162	4.089	95.83	-	65	45	4.091	95.38	99.53	-	66	32	3.68	3.753	3.831	the cell was compress back to its
22	4.164	4.091	95.83	-	65	43	4.092	95.141	99.28	-	66	30	3.669	3.742	3.856	original size after having broken fixture bolts
23	4.17	4.097	95.83	-	65	43	4.092	95.63	99.79	-	66	30	3.667	3.74	3.858	The cell was on ocv for 192 hrs before it was
24	4.19	4.117	95.83	-	65	43	4.091	94.89	99.02	-	66	31	3.636	3.709	3.851	put back on test.
25	4.19	4.117	95.83	-	65	40	4.091	94.53	98.64	-	66	30	3.63	3.703	3.827	
26	4.1888	4.1138	95.83	-	65	37	4.092	94.34	98.45	-	66	26	3.636	3.709	3.8526	
27	4.1854	4.1124	95.83	-	65	37	4.093	94.08	98.17	-	66	25	3.643	3.716	3.8556	
28	4.1842	4.1112	95.83	-	65	36	4.093	93.45	97.52	-	66	25	3.633	3.706	3.8556	
29	4.1914	4.1184	95.83	-	65	34	4.094	93.11	97.16	-	66	25	3.64	3.713	3.8526	
30	4.1878	4.1148	95.83	-	65	30	4.0916	92.192	96.20	-	66	26	3.634	3.707	3.8528	
31	4.1901	4.1171	95.83	-	65	33	4.0939	91.8	95.79	-	66	28	3.63	3.703	3.852	
32	4.1868	4.1138	95.83	-	66	39	4.0957	90.992	94.95	-	68	30	3.625	3.698	3.851	
33	4.1932	4.1202	95.83	-	66	42	4.0998	89.8512	93.76	-	68	31	3.62	3.693	3.8513	
34	4.2151	4.1421	95.83	-	67	43	4.1137	88.9826	92.85	-	68	34	3.615	3.688	3.8537	
35	4.2325	4.1595	95.83	-	67	43	4.1356	87.1073	90.90	-	68	36	3.615	3.688	-	
36	4.2702	4.1972	95.83	-	67	45	4.1709	84.4497	88.12	-	68	39	3.61	3.683	3.8626	
37	4.3349	4.2619	95.83	-	67	45	4.2349	83.0287	86.64	-	68	39	3.6	3.673	3.8698	
38	4.358	4.285	89.46	-	67	46	-	71.9	75.03	-	68	40	3.6	-	-	
39	4.421	4.348	75.45	-	67	46	-	54.13	56.49	-	68	40	3.6	-	-	
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NSWC-603 - 100 AH AT 90% DOD W/ 2M DSMF

ACTIVATED: 12/27/95

CYCLE #	CHARGE (C/20) CUTOFF VOLTAGE MACCOR	ACTUAL	AMP-HRS	AC IMPED. (mΩ)	TEMP.(°F)	PRESSURE (PSIG)	END OCV CHARGE	DISCHARGE (C/6) AMP-HRS	% RETURNS	AC IMPED. (mΩ)	RETURN Whr	PRESSURE (PSIG)	DELTA VOLTAGE	PLATEAU VOLT.	END OCV DISCH.	REMARKS
1	-	4.0817	95.83	3	66	30	4.065	91.54	95.52	3	353.3	46	-	3.86	3.8544	12/28/95
2	-	4.0989	95.83	3	66	-	4.083	95.91	100.08	3	370.2	-	-	3.86	3.8454	
3	-	4.0997	95.83	3	66	-	4.0826	94.44	98.55	3	364.5	-	-	3.86	3.839	
4	-	4.1069	95.83	4	66	-	4.0877	95.83	100.00	4	369.9	-	-	3.86	3.836	
5	-	4.1063	95.83	4	66		4.0874	95.77	99.94	4	369.2	-	-	3.855	3.836	1/2/96
6	-	4.1075	95.83	4	66	41	4.088	95.85	100.02	4	369.5	-	-	3.855	3.834	
7	-	4.1076	95.83	4	66	42	4.0879	95.9	100.07	4	369.2	-	-	3.85	3.83	
8	-	4.1069	95.83	4	66	45	4.0868	95.58	99.74	4	367.0	-	-	3.84	3.829	
9	-	4.1082	95.83	4	66	-	4.0876	95.51	99.67	4	366.3	-	-	3.835	3.829	
10	-	4.1097	95.83	4	66	-	4.0887	95.39	99.54	4	365.3	-	-	3.83	3.831	
11	-	4.1125	95.83	4	66	-	4.0905	95.16	99.30	4	364.2	-	-	3.827	3.834	
12	-	4.1169	95.83	4	66	49	4.0945	95.32	99.47	4	364.6	-	-	3.825	3.833	
13	-	4.1204	95.83	4	66	-	4.0979	95.27	99.42	5	364.4	-	-	3.825	3.827	
14	-	4.1245	95.83	4	66	50	4.1015	94.64	98.76	5	361.5	-	-	3.82	3.83	
15	-	4.1343	95.83	5	66	-	4.1099	91.27	95.24	6	347.7	49	-	3.81	3.834	
16	-	4.1775	95.83	5	66	50	4.1514	79.31	82.76	6	300.2	-	-	3.785	3.848	
17	-	4.2994	95.83	5	66	-	4.2994	76.31	79.63	6	286.9	50	-	3.76	3.858	Poor performance on 1-15-96 tookcell off
18	-	4.236	68.03	5	66	50	-	105.84	110.45	-	402.5	62	3.73	3.803	3.85	test at 8 am in the 14th hr of charge.
19	4.153	4.08	95.83	-	66	45	4.092	95.97	100.15	-	363.1	38	3.71	3.783	3.852	put cell back on test on 01-24-96 at 8
20	4.157	4.084	95.83	-	66	45	4.09	95.5	99.66	-	360.2	37	3.699	3.772	3.8522	am on the 18th cycle in discharge.
21	4.162	4.089	95.83	-	66	45	4.091	95.38	99.53	-	358.0	32	3.68	3.753	3.831	the cell was compress back to its
22	4.164	4.091	95.83	-	66	43	4.092	95.141	99.28	-	356.0	30	3.669	3.742	3.856	original size after having broken fixture bolts.
23	4.17	4.097	95.83	-	66	43	4.092	95.63	99.79	-	357.7	30	3.667	3.74	3.856	The cell was on ocv for 192 hrs before it was
24	4.19	4.117	95.83	-	66	43	4.091	94.89	99.02	-	351.9	31	3.636	3.709	3.851	put back on test.
25	4.19	4.117	95.83	-	66	40	4.091	94.53	98.64	-	350.0	30	3.63	3.703	3.827	
26	4.1868	4.1138	95.83	-	66	37	4.092	94.34	98.45	-	349.9	26	3.636	3.709	3.8526	
27	4.1854	4.1124	95.83	-	66	37	4.093	94.08	98.17	-	349.6	25	3.643	3.716	3.8556	
28	4.1842	4.1112	95.83	-	66	36	4.093	93.45	97.52	-	346.3	25	3.633	3.706	3.8556	
29	4.1914	4.1184	95.83	-	66	34	4.094	93.11	97.16	-	345.7	25	3.64	3.713	3.8526	
30	4.1878	4.1148	95.83	-	66	30	4.0916	92.192	96.20	-	341.8	26	3.634	3.707	3.8528	
31	4.1901	4.1171	95.83	-	66	33	4.0939	91.8	95.79	-	339.9	28	3.63	3.703	3.852	
32	4.1868	4.1138	95.83	-	68	39	4.0957	90.992	94.95	-	336.5	30	3.625	3.698	3.851	
33	4.1932	4.1202	95.83	-	68	42	4.0998	89.8512	93.76	-	331.8	31	3.62	3.693	3.8513	
34	4.2151	4.1421	95.83	-	68	43	4.1137	88.9826	92.85	-	328.2	34	3.615	3.688	3.8537	
35	4.2325	4.1595	95.83	-	68	43	4.1356	87.1073	90.90	-	321.3	36	3.615	3.688	-	
36	4.2702	4.1972	95.83	-	68	45	4.1709	84.4497	88.12	-	311.0	39	3.61	3.683	3.8626	
37	4.3349	4.2619	95.83	-	68	45	4.2349	83.0267	86.64	-	305.0	39	3.6	3.673	3.8698	
38	4.358	4.285	89.46	-	68	46	-	71.9	75.03	-	264.1	40	3.6	3.673	-	
39	4.421	4.348	75.45	-	68	46	-	54.13	56.49	-	198.8	40	3.6	3.673	-	
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NSWC- NSWC604													ACTIVATED: 2/29/96
	CHARGE					DISCHARGE (C/6)							
CYCLE #	RATE	CUTOFF VOLT.	AMP-HRS	TEMP.(°F)	PRESSURE (PSIG)	AMP-HRS	% RETURN A	% RETURN B	TEMP.(°F)	PRESSURE (PSIG)	PLATEAU VOLT.		REMARKS
1	C/10	4.178	95.01	RT	-	89.869	94.59	94.59	RT	-	3.75		
2	C/10	4.327	75.25	RT	-	73.647	77.51	97.87	RT	-	-		
3	C/20	4.146	95.01	RT	-	95.02	100.01	100.01	RT	-	-		
4	C/20	4.3	107.44	RT	-	106.56	112.16	99.18	RT	-	-		MACCOR MALFUNCTION OVER THE
5	C/20	4.3	113.303	RT	-	112.119	118.01	98.96	RT	-	-		WEEKEND OF THE 9TH & 10TH OF
6	C/20	4.3	107.266	RT	-	106.1	111.67	98.91	RT	-	-		MARCH.
7	C/20	4.182	95.01	RT	46	95.33	100.34	100.34	RT	-	3.685		
8	C/20	4.176	95.01	RT	-	95.24	100.24	100.24	RT	-	3.64		
9	C/20	4.155	95.01	RT	59	95.2	100.20	100.20	RT	-	-		
10	C/20	4.156	95.01	RT	-	94.93	99.92	99.92	RT	-	-		
11	C/20	4.175	95.01	RT	-	94.82	99.80	99.80	RT	-	-		
12	C/10	4.23	95.01	RT	66	95.01	100.00	100.00	RT	-	-		
13	C/10	4.265	95.01	RT	-	94.812	99.79	99.79	RT	-	-		
14	C/20	4.166	95.01	RT	-	94.37	99.33	99.33	RT	-	3.55		
15	C/20	4.17	95.01	RT	-	94.47	99.43	99.43	RT	-	3.43		
16	C/20	4.177	95.01	RT	-	94.06	99.00	99.00	RT	28	3.46		BLEED PRESSURE FROM 76 PSIG TO
17	C/20	4.168	95.01	RT	-	94.13	99.07	99.07	RT	-	3.51		28 PSIG MID WAY THROUGH THE 16TH
18	C/20	4.2	95.01	RT	-	94.23	99.18	99.18	RT	-	3.51		CYCLE DISCHARGE.
19	C/20	4.2	95.01	RT	-	94.26	99.21	99.21	RT	49	3.47		
20	C/20	4.2	95.01	RT	-	93.69	98.61	98.61	RT	49	3.47		
21	C/20	4.19	95.01	RT	-	93.51	98.42	98.42	RT	49	3.36		
22	C/20	4.17	95.01	RT	-	93.51	98.42	98.42	RT	49	3.36		
23	C/20	4.22	95.01	RT	-	95.1	100.09	100.09	RT	49	-		
24	C/20	4.3	76.97	RT	-	75.36	79.32	97.91	RT	49	-		
25	C/20	4.3	69.9	RT	-	68.01	71.58	97.30	RT	49	3.35		END OF TEST
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% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC- NSWC604													ACTIVATED: 2/29/96
	CHARGE					DISCHARGE (C/6)							
CYCLE #	RATE	CUTOFF VOLT.	AMP-HRS	TEMP.(°F)	PRESSURE (PSIG)	AMP-HRS	% RETURNS A	% RETURNS B	RETURN Whr	PRESSURE (PSIG)	PLATEAU VOLT.	REMARKS	
1	C/10	4.178	95.01	RT	-	89.869	94.59	94.59	337.0	-	3.75		
2	C/10	4.327	75.25	RT	-	73.647	77.51	97.87	276.2	-	3.75		
3	C/20	4.146	95.01	RT	-	95.02	100.01	100.01	356.3	-	3.75		
4	C/20	4.3	107.44	RT	-	106.56	112.16	99.18	399.6	-	3.75	MACCOR MALFUNCTION OVER THE	
5	C/20	4.3	113.303	RT	-	112.119	118.01	98.96	420.4	-	3.75	WEEKEND OF THE 9TH & 10TH OF	
6	C/20	4.3	107.266	RT	-	106.1	111.67	98.91	397.9	-	3.75	MARCH.	
7	C/20	4.182	95.01	RT	46	95.33	100.34	100.34	351.3	-	3.685		
8	C/20	4.176	95.01	RT	-	95.24	100.24	100.24	346.7	-	3.64		
9	C/20	4.155	95.01	RT	59	95.2	100.20	100.20	346.5	-	3.64		
10	C/20	4.156	95.01	RT	-	94.93	99.92	99.92	345.5	-	3.64		
11	C/20	4.175	95.01	RT	-	94.82	99.80	99.80	345.1	-	3.64		
12	C/10	4.23	95.01	RT	66	95.01	100.00	100.00	345.8	-	3.64		
13	C/10	4.265	95.01	RT	-	94.812	99.79	99.79	345.1	-	3.64		
14	C/20	4.166	95.01	RT	-	94.37	99.33	99.33	335.0	-	3.55		
15	C/20	4.17	95.01	RT	-	94.47	99.43	99.43	324.0	-	3.43		
16	C/20	4.177	95.01	RT	-	94.06	99.00	99.00	325.4	28	3.46	BLEED PRESSURE FROM 76 PSIG TO	
17	C/20	4.168	95.01	RT	-	94.13	99.07	99.07	330.4	-	3.51	28 PSIG MID WAY THROUGH THE 16TH	
18	C/20	4.2	95.01	RT	-	94.23	99.18	99.18	330.7	-	3.51	CYCLE DISCHARGE.	
19	C/20	4.2	95.01	RT	-	94.26	99.21	99.21	327.1	49	3.47		
20	C/20	4.2	95.01	RT	-	93.69	98.61	98.61	325.1	49	3.47		
21	C/20	4.19	95.01	RT	-	93.51	98.42	98.42	314.2	49	3.36		
22	C/20	4.17	95.01	RT	-	93.51	98.42	98.42	314.2	49	3.36		
23	C/20	4.22	95.01	RT	-	95.1	100.09	100.09	319.5	49	3.36		
24	C/20	4.3	76.97	RT	-	75.36	79.32	97.91	253.2	49	3.36		
25	C/20	4.3	69.9	RT	-	68.01	71.58	97.30	227.8	49	3.35	END OF TEST	
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% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC- NSWC605

ACTIVATED: 4/16/96

CYCLE #	CHARGE RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°F)	PRESSURE (PSIG)	DISCHARGE (C/6) DISCHARGE RATE	AMP-HRS	% RETURNS	TEMP.(°F)	OCV	PRESSURE (PSIG)	PLATEAU VOLT.	REMARKS
1	C/20	4 0984	4 0601	93 15	RT	40	C/6	88 9563	95 50	RT	3 847	-	3 7	
2	C/20	4 1344	4 0751	93 15	RT	-	C/6	91 8544	98 61	RT	3 842	-	3 7	
3	C/20	4 1291	4 0751	93 15	RT	75	C/6	91 1842	97 89	RT	3 839	50	3 69	BLEED PSI FROM 75 TO 50 PSIG
4	C/20	4 1131	4 0716	93 15	RT	-	C/6	91 225	97 93	RT	3 8384	-	3 69	
5	C/20	4 1356	4 0763	93 15	RT	-	C/6	91 709	98 45	RT	3 8338	-	3 69	
6	C/20	4 1326	4 0744	93 15	RT	-	C/6	91 5408	98 27	RT	3 8384	-	3 69	
7	C/20	4 1379	4 0806	93 15	RT	-	C/6	92 4216	99 22	RT	3 837	76	3 74	
8	C/20	4 134	4 0841	93 15	RT	-	C/6	91 764	98 51	RT	3 8365	-	3 75	
9	C/20	4 1307	4 0898	93 15	RT	-	C/6	91 9761	98 74	RT	3 8393	-	3 75	
10	C/20	4 1372	4 0945	93 15	RT	96	C/6	92 4001	99 19	RT	3 8371	50	3 75	BLEED PSI FROM 96 TO 50 PSIG
11	C/20	4 1367	4 0939	93 15	RT	75	C/6	92 3148	99 10	RT	3 8369	-	3 75	
12	C/20	4 1375	4 0941	93 15	RT	-	C/6	91 5059	98 23	RT	3 8885	-	3 75	
13	C/20	4 1429	4 0992	93 15	RT	-	C/6	91 8221	98 57	RT	3 8395	60	-	BLEED PSI FROM 82 TO 60 PSIG
14	C/20	4 1447	4 1008	93 15	RT	72	C/6	91 9288	98 69	RT	3 8361	50	3 76	BLEED PSI FROM 72 TO 60 PSIG
15	C/20	4 1345	4 0902	93 15	RT	-	C/6	89 6838	96 28	RT	3 8345	-	3 76	
16	C/20	4 1365	4 0914	93 15	RT	-	C/6	89 6707	96 26	RT	3 8352	68	3 76	
17	C/20	4 1422	4 0966	93 15	RT	-	C/6	90 2459	96 88	RT	3 8384	68	3 76	
18	C/20	4 1409	4 0953	93 15	RT	-	C/6	89 6282	96 22	RT	3 8399	60	3 76	
19	C/20	4 1423	4 0967	93 15	RT	-	C/6	89 5218	96 10	RT	3 8391	60	3 76	
20	C/20	4 1374	4 0918	93 15	RT	-	C/6	88 4013	94 90	RT	3 8391	-	3 76	
21	C/20	4 1384	4 0929	93 15	RT	-	C/6	88 5608	95 07	RT	3 835	-	3 76	
22	C/20	4 1371	4 0915	93 15	RT	-	C/6	88 2533	94 74	RT	3 8381	-	3 76	
23	C/20	4 1375	4 0918	93 15	RT	63	C/6	87 6661	94 11	RT	3 841	63	3 76	
24	C/20	4 141	4 0952	93 15	RT	-	C/6	87 9447	94 41	RT	3 8381	64	3 76	
25	C/20	4.1359	4 0903	93 15	RT	-	C/6	86 1458	92 48	RT	3 8357	60	3 76	
26	C/20	4 1597	4 1139	98 325	RT	-	C/6	88 1528	89 65	RT	3 835	66	3 76	
27	C/20	4 1525	4 1062	98 325	RT	-	C/6	86 3501	87 82	RT	3 8374	-	3 76	
28	C/20	4 1649	4 1184	95 523	RT	-	C/6	86 346	90 39	RT	3 8383	-	3 76	
29	C/20	4 1649	4 1181	95 344	RT	-	C/6	84 262	88 38	RT	3 8381	63	3 76	
30	C/20	4 1886	4 1415	31 1263	RT	-	C/6	85 0324	86 48	RT	3 8383	63	3 76	
31	C/20	4 1659	4 1184	70 0945	RT	-	C/6	79 8685	85 74	RT	3 8391	63	3 76	
32	C/20	5 1077	-	67 6843	RT	-	C/6	0 0003		RT	2 0345			Maccor cycle machine toggled through 3
33	C/20	5 1077	-	-	RT	-	C/6	-	-	RT	-			cycles rapidly then vented at the safety
34	C/20	5 1077	-	-	RT	-	C/6	-	-	RT	-	-	-	vent closest to the negative terminal This
35														terminal was later found to have developed
36														a low resistance short due to dendrite
37														deposits across the GTM seal
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49														LAST UPDATED: 05-24-96
50														

NSWC- NSWC605 — **ACTIVATED: 4/16/96**

CHARGE							DISCHARGE (C/6)								
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°F)	PRESSURE (PSIG)	DISCHARGE RATE	AMP-HRS	% RETURNS	RETURN Whr	OCV	PRESSURE (PSIG)	PLATEAU VOLT.	REMARKS
1	C/20	4.0984	4.0601	93.15	RT	40	C/6	88.9563	95.50	329.1	3.847	-	3.7	
2	C/20	4.1344	4.0751	93.15	RT	-	C/6	91.8544	98.61	339.9	3.842	-	3.7	
3	C/20	4.1291	4.0751	93.15	RT	75	C/6	91.1842	97.89	336.5	3.839	50	3.69	BLEED PSI FROM 75 TO 50 PSIG
4	C/20	4.1131	4.0716	93.15	RT	-	C/6	91.225	97.93	336.6	3.8384	-	3.69	
5	C/20	4.1356	4.0763	93.15	RT	-	C/6	91.709	98.45	338.4	3.8338	-	3.69	
6	C/20	4.1326	4.0744	93.15	RT	-	C/6	91.5408	98.27	337.8	3.8384	-	3.69	
7	C/20	4.1379	4.0806	93.15	RT	-	C/6	92.4216	99.22	345.7	3.837	76	3.74	
8	C/20	4.134	4.0841	93.15	RT	-	C/6	91.764	98.51	344.1	3.8365	-	3.75	
9	C/20	4.1307	4.0898	93.15	RT	-	C/6	91.9761	98.74	344.9	3.8393	-	3.75	
10	C/20	4.1372	4.0945	93.15	RT	96	C/6	92.4001	99.19	346.5	3.8371	50	3.75	BLEED PSI FROM 96 TO 50 PSIG
11	C/20	4.1367	4.0939	93.15	RT	75	C/6	92.3148	99.10	346.2	3.8369	-	3.75	
12	C/20	4.1375	4.0941	93.15	RT	-	C/6	91.5059	98.23	343.1	3.8885	-	3.75	
13	C/20	4.1429	4.0992	93.15	RT	-	C/6	91.8221	98.57	344.3	3.8395	60	3.75	BLEED PSI FROM 82 TO 60 PSIG
14	C/20	4.1447	4.1008	93.15	RT	72	C/6	91.9288	98.69	345.7	3.8361	50	3.76	BLEED PSI FROM 72 TO 60 PSIG
15	C/20	4.1345	4.0902	93.15	RT	-	C/6	89.6838	96.28	337.2	3.8345	-	3.76	
16	C/20	4.1365	4.0914	93.15	RT	-	C/6	89.6707	96.26	337.2	3.8352	68	3.76	
17	C/20	4.1422	4.0966	93.15	RT	-	C/6	90.2459	96.88	339.3	3.8384	68	3.76	
18	C/20	4.1409	4.0953	93.15	RT	-	C/6	89.6282	96.22	337.0	3.8399	60	3.76	
19	C/20	4.1423	4.0967	93.15	RT	-	C/6	89.5218	96.10	336.6	3.8391	60	3.76	
20	C/20	4.1374	4.0918	93.15	RT	-	C/6	88.4013	94.90	332.4	3.8391	-	3.76	
21	C/20	4.1384	4.0929	93.15	RT	-	C/6	88.5608	95.07	333.0	3.835	-	3.76	
22	C/20	4.1371	4.0915	93.15	RT	-	C/6	88.2533	94.74	331.8	3.8381	-	3.76	
23	C/20	4.1375	4.0918	93.15	RT	63	C/6	87.6661	94.11	329.6	3.841	63	3.76	
24	C/20	4.141	4.0952	93.15	RT	-	C/6	87.9447	94.41	330.7	3.8381	64	3.76	
25	C/20	4.1359	4.0903	93.15	RT	-	C/6	86.1458	92.48	323.9	3.8357	60	3.76	
26	C/20	4.1597	4.1139	98.325	RT	-	C/6	88.1528	89.65	331.5	3.835	66	3.76	
27	C/20	4.1525	4.1062	98.325	RT	-	C/6	86.3501	87.82	324.7	3.8374	-	3.76	
28	C/20	4.1649	4.1184	95.523	RT	-	C/6	86.346	90.39	324.7	3.8383	-	3.76	
29	C/20	4.1649	4.1181	95.344	RT	-	C/6	84.262	88.38	316.8	3.8381	63	3.76	
30	C/20	4.1886	4.1415	31.1263	RT	-	C/6	85.0324	86.48	319.7	3.8383	63	3.76	
31	C/20	4.1659	4.1184	70.0945	RT	-	C/6	79.8685	85.74	300.3	3.8391	63	3.76	
32	C/20	5.1077	-	67.6843	RT	-	C/6	0.0003		300.3	2.0345		3.76	Maccor cycle machine toggled through 3
33	C/20	5.1077	-	-	RT	-	C/6	-	-	300.3	-		3.76	cycles rapidly then vented at the safety
34	C/20	5.1077	-	-	RT	-	C/6	-	-	300.3	-	-	3.76	vent closest to the negative terminal. This
35														terminal was later found to have developed
36														a low resistance short due to dendrite
37														deposits across the GTM seal.
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49														**LAST UPDATED: 05-24-96**
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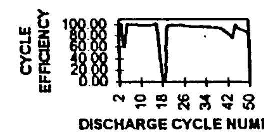
							NSWC- NSWC606							ACTIVATED: 4/16/96
	CHARGE (C/20 = 4.81Amp., C/30 = 3.21Amp.)						DISCHARGE (C/6 = 16.04Amp., C/20 = 4.81Amp.)							90% 0.5F/M = 96.26 AHr. (Rated Capacity)
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°F)	PRESSURE (PSIG)	DISCHARG RATE	AMP-HRS	% RETURNS	RETURN Whr	OCV	PRESSURE (PSIG)	PLATEAU VOLT.	REMARKS
1	C/20	4.1022	4.065	96.26	RT	40	C/6	92.5449	96.14	350.7	3.847	-	3.79	
2	C/20	4.1196	4.0829	96.26	RT	-	C/6	96.4063	100.15	365.4	3.8425	-	3.79	
3	C/20	4.119	4.0819	96.26	RT	50	C/6	96.1011	99.83	362.3	3.8414	-	3.77	
4	C/20	5.1093	4.0716	96.26	RT	-	C/6	58.5112	60.78	220.6	3.8435	-	3.77	AC Imp probes click Maccor from charge to disch
5	C/20	4.1488	4.0829	96.26	RT	50	C/6	96.1352	99.87	349.9	3.8435	-	3.64	
6	C/20	4.1509	4.0829	96.26	RT	-	C/6	95.4031	99.11	338.7	3.8482	-	3.55	
7	C/20	4.1602	4.0569	96.26	RT	-	C/6	96.2697	100.01	341.8	3.8433	50	3.55	
8	C/20	4.1309	4.0842	96.26	RT	-	C/6	96.0944	99.83	341.1	3.8384	-	3.55	
9	C/20	4.1368	4.0834	96.26	RT	-	C/6	95.745	99.46	339.9	3.8405	-	3.55	
10	C/20	4.1476	4.0852	96.26	RT	-	C/6	95.61	99.32	358.5	3.8409	30	3.75	
11	C/20	4.1566	4.0877	96.26	RT	-	C/6	95.488	99.20	358.1	3.8391	21	3.75	
12	C/20	4.1618	4.091	96.26	RT	-	C/6	95.1292	98.82	356.7	3.8401	21	3.75	
13	C/20	4.1705	4.0965	96.26	RT	-	C/6	95.0046	98.70	356.3	3.8407	10	3.75	
14	C/20	4.177	4.1029	96.26	RT	-	C/6	95.128	98.82	356.7	3.8405	50	3.75	
15	C/20	4.1946	4.1064	96.26	RT	-	C/6	95.1746	98.87	356.9	3.8403	50	3.75	
16	C/20	4.2181	4.1084	96.26	RT	-	C/6	96.0528	99.78	360.2	3.844	10	3.75	
17	C/20	4.3001	3.9217	44.9616	RT	-	C/6	45.7995	47.58	171.7	3.8842	10	3.75	poor performance due to leaking cell
18	C/20	4.3001	3.8818	2.7899	RT	-	C/6	3.357	3.49	12.6	3.8501	10	3.75	electrolyte lost due to leaking cell
19	C/20	4.3001	3.306	3.3842	RT	-	C/6	3.4875	3.62	13.1	3.8524	10	3.75	repaired suspected source of leak
20	C/20	4.0986	4.0785	94.55	RT	-	C/6	93.0772	96.69	349.0	3.8375	10	3.75	restarted test after adding lost electrolyte, 40cc
21	C/20	4.1134	4.0927	96.26	RT	-	C/6	94.667	98.34	355.0	3.8373	10	3.75	
22	C/20	4.1195	4.0983	96.26	RT	-	C/6	94.8678	98.55	368.1	3.8374	43	3.88	
23	C/20	4.1232	4.1016	96.26	RT	-	C/6	95.1175	98.81	369.1	3.8364	43	3.88	
24	C/20	4.1237	4.1016	96.26	RT	-	C/6	94.964	98.65	368.5	3.8363	43	3.88	
25	C/20	4.1238	4.1013	96.26	RT	-	C/6	94.9662	98.66	368.5	3.8302	43	3.88	
26	C/20	4.1267	4.1023	96.26	RT	-	C/6	93.9784	97.63	364.6	3.835	-	3.88	
27	C/20	4.1326	4.1074	96.26	RT	-	C/6	93.6328	97.27	363.3	3.8373	-	3.88	
28	C/20	4.1416	4.116	96.26	RT	-	C/6	93.35	96.98	362.2	3.8404	-	3.88	
29	C/20	4.1541	4.128	96.26	RT	-	C/6	93.5797	97.22	363.1	3.8419	-	3.88	
30	C/20	4.1645	4.1381	96.26	RT	-	C/6	93.2744	96.90	361.9	3.8433	-	3.88	
31	C/20	4.1763	4.1494	96.26	RT	44	C/6	93.2205	96.84	361.7	3.8438	-	3.88	
32	C/20	4.1862	4.1589	96.26	RT	45	C/6	92.7819	96.39	360.0	3.8451	-	3.88	
33	C/20	4.1962	4.1683	96.26	RT	45	C/6	92.6467	96.25	358.5	3.8449	41	3.87	
34	C/20	4.2051	4.1767	96.26	RT	-	C/6	92.1666	95.75	356.7	3.8447		3.87	
35	C/20	4.2177	4.1887	96.26	RT	-	C/6	91.7514	95.32	355.1	3.8445	-	3.87	
36	C/20	4.2321	4.2027	96.26	RT	45	C/6	91.2843	94.83	353.3	3.8448	-	3.87	
37	C/20	4.2489	4.219	96.26	RT	45	C/6	90.9835	94.52	352.1	3.8449	-	3.87	
38	C/20	4.2662	4.2357	96.26	RT	-	C/6	90.5454	94.06	350.4	3.8449	-	3.87	
39	C/20	4.285	4.2537	96.26	RT	48	C/6	89.9253	93.42	348.0	3.8456	-	3.87	
40	C/20	4.3	4.2676	95.2886	RT	50	C/6	88.5559	92	342.7	3.8465	-	3.87	
41	C/20	4.3	4.2668	92.2224	RT	-	C/6	85.5121	88.83	330.9	3.848	-	3.87	
42	C/20	4.3	4.2659	89.0717	RT	-	C/6	82.0606	85.25	317.6	3.8503	-	3.87	
43	C/20	4.3	4.2645	85.4196	RT	57	C/6	78.3181	81.36	303.1	3.8532	-	3.87	
44	C/20	4.3	4.2631	81.6361	RT	60	C/6	74.2449	77.13	287.3	3.8562	-	3.87	Suspended after 7.33 hrs. into charge; 35.277Ah.
45	C/30	4.3	4.2742	85.1249	RT	-	C/20	94.4371	98.1	369.2	3.787	65	3.91	49.8476Ah additional charged at C/30.
46	C/30	4.2623	4.2362	96.26	RT	-	C/20	89.4862	92.96	350.8	3.7882	-	3.92	New file no. is NSWC606c
47	C/30	4.2666	4.2378	96.26	RT	65	C/20	88.2491	91.68	345.9	3.7866	-	3.92	
48	C/30	4.2738	4.2429	96.26	RT	67	C/20	86.2225	89.57	338.9	3.7849	-	3.93	
49	C/30	4.2913	4.2564	96.26	RT	73	C/20	83.3267	86.56	327.5	3.7851	-	3.93	
50	C/30	4.3	4.2603	92.92	RT	-	C/20	77.307	80.31	303.0	3.7882	82	3.92	**LAST UPDATED: 06-25-96, TEST TERMINATED**

Cell 606 cycling eff. at rated capacity



NSWC- NSWC 607										Rated Capacity;Ahr.:	95.17	
CHARGE (10 hour rate, except as shown)							DISCHARGE (6 hour rate)					Activated: 7/26/96
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP HRS	TEMP. (°C)	PRESSURE (PSIG)	DISCHARGE RATE	OCV	AMP HRS	% RETURN	PLATEAU VOLT.	REMARKS
1	C/10	4.101	3.1206	95.17	-2	60	C/6	4.0635	86.559	90.95	3.94	file nswc607
2	C/10	4.153	3.886	95.17	-2		C/6	4.116	94.913	99.73	3.95	
3	C/10	4.156	3.886	95.17	-2		C/6	4.119	96.033	100.91	3.95	
4	C/10	4.148	3.881	95.17	-2		C/6	4.11	94.855	99.67	3.94	
5	C/10	4.155	3.882	95.17	-2		C/6	4.115	95.117	99.94	3.93	
6	C/10	4.162	3.882	95.17	-2	60	C/6	4.118	94.38	99.17	3.94	
7	C/10	4.161	3.878	95.17	-2	32	C/6	4.105	88.186	92.66		
8	C/10	4.162	3.878	95.17	-2		C/6	4.106	82.592	86.78	3.92	
9	C/10	4.224	3.878	95.17	-2		C/6	4.166	89.803	94.36	3.9	
10	C/10	4.217	3.879	95.17	-2		C/6	4.159	91.448	96.09	3.91	
11	C/10	4.237	3.878	95.17	-2		C/6	4.172	92.644	97.35	3.91	
12	C/10	4.245	3.881	95.17	-2		C/6	4.177	94.63	99.43		
13	C/10	4.258	3.878	95.17	-2		C/6	4.185	94.818	99.63	3.9	
14	C/10	4.26	3.877	95.17	-2	40	C/6	4.183	91.683	96.34		
15	C/10	4.284	3.881	95.17	-2		C/6	4.199	90.945	95.56	3.9	
16	C/10	4.3	3.878	94.79	-2	30	C/6	4.217	90.721	95.33		
17	C/10	4.3	3.881	91.43	-2		C/6	4.215	87.255	91.68		
18	C/10	4.3	3.879	88.164	-2	27	C/6	4.212	83.054	87.27		
19	C/10	4.3	3.883	83.366	-2	24	C/6	4.207	78.431	82.41		
20	C/10	4.3	3.883	79.353	-2		C/6	4.205	73.794	77.54	3.9	added 60g El
21	C/20	4.3	3.885	85.179	-2	60	C/6	4.251	88.294	92.78	3.8	file nswc607B
22	C/20	4.3	3.882	90.987	-2	60	C/6	4.255	87.019	91.44		file nswc607C
23	C/20	4.3	3.882	93.906	-2		C/6	4.258	84.538	88.83	3.8	
24	C/20	4.3	3.883	91.626	-2	51	C/6	4.258	82.411	86.59		power failure
25	C/20	4.3	3.881	95.081	-2	50	C/6	4.267	81.149	85.27	3.8	file nswc607D
26	C/20	4.3	3.882	91.616	-2	50	C/6	4.255	75.835	79.68	3.8	
27	C/20	4.3	3.888	76.699	-2		C/6	4.252	72.653	76.34	3.8	test ended
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% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC-701 Rated Capacity;Ahr.: 112.71

Activated: 7/26/96

CHARGE (10 hour rate, except as noted)							DISCHARGE (6 hour rate except as noted)					
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARG RATE	OCV	AMP-HRS	% RETURN	PLATEAU VOLT.	REMARKS
1	C/10	4.0921	4.06	112.71	AMB		C/6		109.8410	97.5	3.8504	Vented - Repaired.
2	•	4.1059	4.07	•	•		•		111.5530	99.0	3.8565	
3	•	4.1112	4.07	•	•		•		112.4320	99.8	3.8591	
4	•	4.1227	4.08	•	•		•		110.8680	98.4	3.8589	
5	•	4.1037	4.07	•	•		•		110.5640	98.3	3.8602	
6	•	4.1058	4.07	•	•		•		110.9140	98.4	3.8610	
7	•	4.1068	4.08	•	•		•		110.8310	98.3	3.8614	
8	•	4.0940	4.01	•	•		•		108.2440	95.8	3.8622	
9	•	4.1081	4.08	•	•		•		111.3270	98.6	3.8697	
10	•	4.1079	4.08	•	•		•		110.7560	98.3	3.8635	
11	•	4.1078	4.08	•	•		•		110.1940	97.8	3.8620	
12	•	4.1073	4.07	•	•		•		101.6080	90.1	3.8595	
13	•	4.1080	4.07	•	•		•		108.0350	95.9	3.8580	
14	•	4.1092	4.07	•	•		•		106.5530	94.5	3.8555	
15	•	4.1137	4.07	•	•		•		105.4350	93.5	3.8593	
16	•	4.1198	4.08	•	•		•		104.0040	92.3	3.8540	
17	•	4.1288	4.08	•	•		•		102.2870	90.80	3.8558	
18	•	4.1440	4.10	•	•		•		100.8180	89.40	3.8626	
19	•	4.1677	4.17	•	•		•		99.1387	88.00	3.8344	
20	•	4.1921	4.14	•	•		•		97.5720	86.60	3.8691	
21	•	4.2298	4.18	•	•		•		97.6107	86.60	3.8580	
22	•	4.2874	4.21	•	•		•		95.8758	85.10	3.8998	
23	•	4.2999	4.24	109.827	•		•		91.4551	86.10	3.8797	
24	•	4.2999	4.2300	100.413	•		•		82.5286	73.20	3.8260	
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% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC- NSWC702 Rated Capacity;Ahr.:114.04

CHARGE (10 hour rate, ecept as shown)

DISCHARGE (6 hour rate)

Activated: 7/20/96

CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	RESSURE (PSIG)	DISCHAR RATE	OCV	AMP-HRS	% RETURN	PLATEAU VOLT.	REMARKS
1	C/10	4.0912	4.0605	114.04	RT		C/6	3.7702	111.11	97.40	3.855	
2	C/10	4.102	4.0726	114.04	RT		C/6	3.7637	113.92	99.98	3.85	
3	C/10	4.1045	4.073	114.04	RT		C/6	3.7608	113.907	99.88	3.835	
4	C/10	4.1098	4.0741	114.04	RT		C/6	3.7667	113.785	99.77	3.83	
5	C/10	4.1159	4.0759	114.04	RT		C/6	3.984	3.885			Test Suspended
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% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC- NSWC703 Rated Capacity;Ahr.:111.89

CHARGE (10 hour rate, ecept as shown)							DISCHARGE (6 hour rate) Activated: 7/20/96					
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	RESSURE (PSIG)	DISCHAR RATE	OCV	AMP-HRS	% RETURN	PLATEAU VOLT.	REMARKS
1	C/10	4.0972	4.0614	111.89	RT		C/6	3.7664	109.228	97.62	3.848	
2	C/10	4.1053	4.0718	111.89	RT		C/6	3.758	111.7	99.83	3.849	
3	C/10	4.1081	4.072	111.89	RT		C/6	3.7684	111.44	99.60	3.83	
4	C/10	4.1129	4.074	111.89	RT		C/6	3.7639	111.649	99.78	3.83	
5	C/10	4.1159	4.074	111.89	RT		C/6		5.126			Test Suspended
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% RETURN A: PERCENTAGE OF RATED CAPACITY
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC-706										Rated Capacity;Ahr.:116.29			
CHARGE (10 hour rate, except as noted)							DISCHARGE (6 hour rate except as noted)						Activated:1/3/97 Test start: 1/6/97
CYCLE	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C	RESSUR (PSIG)	ISCHAR RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	10hrs.	4.117	3.3599	116.29	R/T	87	6hrs.	4.082	112.195	433.72	3.86	STL was below 60F
2	"	4.1358	3.7929	"	"	75	"	4.1004	115.643	446.49	"	Test stopped to change to 4hr. rate. 29.07 ampheres
3	4hrs.	4.1996	3.8634	"	"	52	4hrs.	4.1077	114.643	438.34	3.83	Test procedure: NSWC706a
4	"	4.18	3.8171	"	"		"	4.0847	109.205	415.94	3.825	
5	"	4.2072	3.8152	"	"	53	"	4.1089	114.532	436.99	3.82	
6	"	4.2215	3.8139	"	"	67	"	4.1203	115.6	441.93	"	
7	"	4.2226	3.812	"	"		"	4.1202	115.51	442.46	"	
8	"	4.228	3.8097	"	"		"	"	115.141	441.51	"	
9	"	4.227	3.8095	"	"	70	"	4.1184	114.508	439.19	"	
10	"	4.2255	3.8078	"	"		"	4.1156	113.778	436.27	"	
11	"	4.2268	3.8068	"	"		"	4.1144	112.722	431.96	"	
12	"	4.2348	3.8093	"	"		"	4.1181	111.658	427.63	3.818	
13	"	4.249	3.814	"	"		"	4.1275	110.372	422.47	3.82	
14	"	4.2679	3.8188	"	"		"	4.141	108.679	415.82	"	
15	"	4.2929	3.8234	"	"		"	4.1596	106.849	408.05	"	
16	"	4.2999	3.878	112.29	"		"	4.1618	100.933	385.75	3.81	80% DOD = 93.03 Ahr.
17	"	4.3	3.8318	105.633	"	10	"	4.1558	92.35	351.85	3.8	
18	"	4.3	3.838	97.9	"		"	4.1506	89.094	339.25	3.81	
19	"	4.3	3.8361	98.43	"		"	4.1507	85.557	325.79	3.8	70% DOD = 81.40 Ahr.
20	"	4.3	3.8336	94.046	"	10	"	4.151	81.107	308.43	"	
21	20hrs.	4.1931	3.8031	116.29	"		10hrs.	4.1595	96.7418	374.38	3.85	Test procedure: NSWC706b
22	"	4.2078	3.7978	"	"	10	"	4.1724	95.1068	367.71	"	1/17/97
23	"		3.8075									

NSWC-787 Rated Capacity;Ahr.:124.49

	CHARGE (10 hour rate, except as noted)						DISCHARGE (3 hour rate except as noted)					Activated:12/13/98 Placed under load: 12/17/98 93hrs soak
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARG RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	10hr.	4.097	3.3781	124.49	R/T	65charge	8hr.		120.8	466.9	3.85	8hr discharges are at 20.74 ampheres.
2	"	4.1106	3.7811	"	"		8hr		123.9	478.8	3.85	10hr. charges are at 12.45 ampheres
3	"	4.1149	3.778	"	"	80charge	3hr.		123.4	467.1	3.78	3hr. discharges are at 41.49 ampheres.
4	"	4.1206	3.8033	"	"		3hr.		122.7	464.4	"	
5	"	4.1287	3.8106	"	"	102discharg	3hr.		119.7	453.4	"	
6	"	4.1536	3.8436	"	"		8hr.		128.6	496.8	3.85	changed cycle limit to capacity cutoff Program looped to 8hr. rate.
7	"	4.138	3.7918	"	"		3hr.		116.6	441.2	3.78	
8	"	4.1643	3.8344	"	"		3hr.		126.3	479.7	3.79	
9	"	4.1718	3.8336	"	"	90charge	3hr.		122.5	464.2	"	
10	"	4.1797	3.8358	"	"		3hr.		123.3	467.5	3.78	
11	"	4.1815	3.8347	"	"		3hr.		122.5	464.2	"	
12	"	4.1856	3.8328	"	"		3hr.		122.8	465.2	"	
13	"	4.1848	3.8308	"	"		3hr.		123	466.2	"	
14	"	4.179	3.828	"	"		3hr.		121.7	460.9	"	
15	"	4.1836	3.8298	"	"		3hr.		120.9	458.4	"	
16	"	4.1918	3.833	"	"		3hr.		120.1	455.6	"	
17	"	4.202	3.8361	"	"		3hr		120.2	456.4	"	
18	"	4.209	3.838	"	"		3hr		119.9	455.3	"	
19	"	4.2151	"	"	"		3hr		119.2	452.9	"	
20	"	4.223	3.839	"	"		3hr.		118.5	450.1	3.787	
21	"	4.2298	3.8404	"	"		3hr		117.6	446.7	"	
22	"	4.2374	3.8405	"	"		3hr.		115.9	440.0	3.78	
23	"	4.246	3.8413	"	"		3hr		113.1	429.1	"	
24	"	4.265	3.8425	"	"		3hr.		110.5	418.9	"	
25	"	4.299	3.846	"	"	85discharge	3hr		108.6	411.4	3.77	
26	"	4.3	3.8507	116.28	"		3hr.		99.92	377.4	3.76	File shows cell had erradic charge voltages for 2hrs. into 27th
27	"		3.859									cycle then the cell vented. Charge control would prevent this
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% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC-708 Rated Capacity;Ahr.:113.17

CHARGE (10 hour rate, except as noted) DISCHARGE (3 hour rate except as noted)

Activated:12/17/96 Test Start:12/19/96 Test End:1/5/97

CYCLE	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C	RESSURE (PSIG)	DISCHARG RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	10hr.	4.0146	3.4844	113.17	R/T	50	6hr.	4.0604	110.04	424.80	3.86	53 hrs. soak prior to test.
2	"	4.1078	3.7936	"	"	90	6hr.	4.0743	112.851	434.89	0.85	
3	"	4.1127	3.7967	"	"		3hr.	4.0768	111.909	423.36	3.79	3 Hr. rate discharge load is 37.72 Amp.
4	"	4.1229	3.8263	"	"		"	4.0839	109.922	415.71	3.787	
5	"	4.1458	3.833	"	"	88	"	4.103	108.442	409.86	3.79	
6	"	4.1787	3.8408	"	"		"	4.1336	114.58	433.99	"	
7	"	4.1677	3.8863	"	"		"	4.1227	114.347	432.79	"	
8	"	4.1574	3.838	"	"		"	4.1574	113.96	431.21	3.787	
9	"	4.1495	3.8349	"	"		"	4.1065	113.123	428.08	3.79	
10	"	4.1483	3.8309	"	"		"	4.1054	111.994	423.86	"	
11	"	4.1552	3.8309	"	"		"	4.1103	110.63	418.61	"	
12	"	4.1627	3.834	"	"		"	4.1167	108.918	412.01	3.787	
13	"	4.1764	3.8353	"	"		"	4.13	110.517	418.37	3.79	
14	"	4.1743	3.837	"	"		"	4.1293	110.721	419.10	"	
15	"	4.1705	3.8364	"	"		"	4.1258	110.01	416.40	3.78	
16	"	4.1663	3.8351	"	"		"	4.1219	108.713	411.48	"	
17	"	4.1751	3.8351	"	"		"	4.1308	109.808	416.04	"	
18	"	4.1759	3.8336	"	"		"	4.132	109.307	414.15	"	
19	"	4.1729	3.8313	"	"		"	4.1293	108.381	410.44	"	
20	"	4.1807	3.831	"	"		"	4.1364	108.187	409.60	"	
21	"	4.1843	3.831	"	"		"	4.1399	107.341	406.28	3.79	
22	"	4.1963	3.8323	"	"	67	"	4.1513	106.87	404.42	3.78	
23	"	4.2119	3.8349	"	"		"	4.1658	106.19	401.73	3.79	
24	"	4.233	3.8412	"	"		"	4.1855	106.457	402.81	"	
25	"	4.2512	3.8447	"	"	66	"	4.2027	106.979	404.63	3.78	90.53 Ah = 80%
26	"	4.2613	3.8455	"	"		"	4.2123	105.187	397.28	3.777	
27	"	4.2727	3.8457	"	"		"	4.224	108.466	410.11	3.78	
28	"	4.2474	3.8404	"	"		"	4.1982	102.774	386.96	3.77	
29	"	4.255	3.8373	"	"		"	4.2049	101.228	380.47	3.75	
30	"	5.1146	3.8383	101.928	"		"	-	-	-		Cell shorted at 8hr.57min.into charge-- cell vented at 9hr.25sec.
31												into charge. Total of 3min. of 11.3Amp. charge of shorted cell.
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NSWC-789 Rated Capacity;Ahr.:113.85

	CHARGE (10 hour rate, except as noted)						DISCHARGE (6 hour rate except as noted)					Activated:11/11/96 Test start: 11/14/96
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARG RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	C/10	4.0987	3.3832	113.85	R/T		6hr.		110.54	428.45		
2	•	4.3	3.794		•		•		135.245	528.70		discharged 7hrs.7min.after charge that was limited by 4.3v only.
3	•	4.119	3.7844	113.85	•		Var /270w		112.58	421.67		Began 270w const. power regime on cycle 3.
4	•	4.1213	4.0754	•	•	85	•		112.576	421.82	3.7	71.3A
5	•	4.126	4.0798	•	•		•		112.91	423.00	3.71	3.628V@1hr. under 270w
6	•	4.1218	4.077	•	•		•		112.55	421.82	3.71	3.6416V •
7	•	4.1169	4.0754	•	•		•		112.167	420.38	•	3.646V •
8	•	4.1159	4.0759	•	•		•		111.865	419.26	3.715	3.647V •
9	•	4.1156	4.076	•	•		•		111.47	417.77	•	3.644V •
10	•	4.1093	4.0705	•	•		•		110.78	415.14	3.71	3.6394V • (32hrs. on OCV prior to cycle 10)
11	•	4.1134	4.0748	•	•	107 - 50	•		110.58	414.30	•	3.634V & 107psi @1hr. under 270w, reduced to 50psi @ low load
12	•	4.1142	4.0748	•	•	45	•		109.4	409.70	3.7	3.6208V •
13	•	4.1165	4.075	•	•		6hr.		108.22	416.65	3.65	
14	•	4.1253	4.0826	•	•	57- 65	•		108.554	417.93	•	
15	•	4.129	4.0854	•	•		•		107.79	414.85	3.845	
16	•	4.1348	4.0897	•	•		•		106.94	411.38	•	
17	•	4.1421	4.0956	•	•		•		105.879	407.03	•	
18	•	4.1527	4.1044	•	•	70 - 77	•		104.665	402.12	3.84	
19	•	4.166	4.1154	•	•	82	•		103.069	395.76	•	
20	•	4.1842	4.1313	•	•	75	•		104.616	402.05	3.838	
21	•	4.209	4.1537	•	•		•		101.62	389.75	3.83	
22	•	4.238	4.177	•	•		•		100.5	385.56	•	
23	•	4.276	4.214	•	•		•		98.127	376.57	3.828	
24	•	4.3	4.2339	•	•		•		92.359	353.80	3.82	
25	•	•	4.2289	•	•		•		82.9	318.34	3.79	at 6hr. 46min. into charge, voltage began to flucuate, 4.2V to 3.9v
26												then 2.88V then plumitted to 0.47V. At 6hr. 56min. the cell vented.
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% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC-710 Rated Capacity;Ahr.:113.98

CHARGE (10 hour rate, except as noted)							DISCHARGE (6 hour rate except as noted)					Activated:11/15/98
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARG RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	10hr.	4.098	4.058	113.98	RT		6hr.		110.38	425.47	3.847	
2	•	4.108	4.0728	•	•		•		113.48	437.09	3.845	
3	•	4.1145	4.0748	•	•		var./270W		113.85	425.95	3.7	3.811V @ 1hr. under 270w
4	•	4.1185	4.0744	•	•		•		108.11	395.64	3.668	3.513V •
5	•	4.1518	4.1071	•	•	160c	•		118.79	444.49	3.7	3.602V •
6	•	4.1258	4.0805	•	•	160c	•		113.99	428.07	3.692	3.589V • press. max. 160 on discharge, 72 ocv
7	•	4.1213	4.0768	•	•	160c - 115d	•		113.47	424.10	3.6939	3.597V • pressure:160 charge, 115 discharge.
8	•	4.1201	4.0751	•	•		•		112.95	422.18	3.693	3.602V •
9	•	4.1245	4.0777	•	•	117c	•		112.48	420.35	3.6926	3.601V •
10	•	4.133	4.084	•	•	88d	•		112.05	418.68	3.688	3.585V •
11	•	4.1412	4.0887	•	•		•		111.91	417.95	3.6885	3.5987V@1hr. under 270w
12	•	4.1433	4.0898	•	•	132c - 75d	•		112.01	418.59	3.692	3.594V@1hr. under 270w
13	•	4.1251	4.077	•	•	120c	6hr.		112.28	431.48	3.84	
14	•	4.129	4.0801	•	•	117c - 71d	•		111.92	430.12	•	
15	•	4.1221	4.074	•	•		•		110.71	425.28	•	
16	•	4.1224	4.0743	•	•		•		110.08	422.80	•	
17	•	4.064	4.0145	•	•		•		94.64	361.49	3.83	
18	•	4.1309	4.082	•	•		•		108.58	417.28	3.84	
19	•	4.0684	4.0203	•	•		•		93.49	357.32	3.83	
20	•	4.1368	4.088	•	•		•		107.02	411.28	3.84	
21	•	4.0749	4.025	•	•		•		91.839	350.91	3.83	
22	•	4.1469	4.095	•	•	70d	•		104.94	402.93	3.84	
23	•	4.1457	4.0936	•	•		•		102.5	393.16	3.837	Current doubling problem shown in Maccor files.
24	•	4.1583	4.1013	•	•	84c - 40d	•		100.39	384.70	3.83	88% return
25	•	4.1748	4.1164	•	•		•		98.074	377.85	•	86.8%return
26	•	4.205	4.1433	•	•	94c	•		95.97	382.55		
27	•	4.2434	4.1717	•	•		•		97.25	371.64		
28	•	4.1987	4.1451	•	•		•		80.816	307.50	3.8	70.%return
29	•	4.3	4.241	•	•		•		80.127	308.04	3.81	
30	•	•	4.237	•	•		•		66.09	251.13	3.79	
31	•	•	4.2331	•	•		•		54.236	204.94	3.78	
32	•	•	4.2277	•	•		•		43.313	162.28	3.75	
33	•	•	4.225	•	•		•		38.254	142.75	3.73	
34	•	•	4.222	•	•		•		34.149	128.98	•	
35	•	•	4.22	•	•		•		32.14	119.28	3.74	
36	•	•	4.218	•	•	75c - 80d	•		30.355	112.49	3.73	
37	•	•	4.217	•	•		•		28.695	108.23	•	
38	•	•	4.215	•	•		•		27.103	100.26	•	
39	•	•	4.213	•	•		•		25.694	94.928	3.74	
40	•	•	4.2119	•	•		•		24.392	90.116	•	
41	•	•	4.2107	•	•		•		23.36	86.285	3.78	
42	•	•	4.2097	•	•		•		22.511	83.165	•	
43	•	•	4.2088	•	•		•		21.816	80.631	3.77	
44	•	•	4.2092	•	•		•		21.208	78.42	•	
45	•	•	4.2068	•	•		•		20.577	76.166	3.78	
46	•	•		•	•		•					test terminated
47												
48												
49												
50												

% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC-711 Rated Capacity,Ahr.:116.38

	CHARGE (4 hour rate, except as noted)						DISCHARGE (4 hour rate except as noted)					Activated:
CYCLE	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C	RESSUR (PSIG)	ISCHAR RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	10hr.	4.0931	3.4214	116.38	RT		6hr.	4.0601	112.653	434.68	3.85	
2	10hr	4.1102	3.799	"	"		6hr.	4.0785	116.351	448.75	3.85	
3	4hr.	4.1682	3.7964	"	"		4hr.	4.0781	115.863	442.07	3.82	
4	"	4.1794	3.8039	"	"		"	4.0774	114.288	435.37	3.818	
5	"	4.182	3.8023	"	"		"	4.0863	117.287	446.87	3.81	
6	"	4.1751	3.7977	"	"		"	4.0811	116.174	442.94	3.81	
7	"	4.1766	3.7951	"	"		"	4.0808	115.59	441.17	3.82	
8	"	4.1818	3.795	"	"		"	4.0817	115.262	440.24	3.82	
9	"	4.1824	3.7937	"	"		"	4.0809	114.768	438.47	3.82	
10	"	4.1823	3.7938	"	"		"	4.0801	114.044	435.77	3.82	
11	"	4.1852	3.7964	"	"		"	4.0815	113.494	433.67	3.82	
12	"	4.1892	3.7989	"	"		"	4.084	112.721	430.64	3.82	
13	"	4.1974	3.8009	"	"		"	4.0895	111.583	426.17	3.81	
14	"	4.2115	3.804	"	"		"	4.0995	110.189	420.71	3.81	
15	"	4.2314	3.8089	"	"		"	4.1158	108.905	415.81	3.81	
16	"	4.2544	3.8129	"	"		"	4.1355	106.365	405.56	3.81	
17	"	4.2851	3.8171	"	"		"	4.1615	108.058	412.86	3.81	
18	"	4.3	3.8174	116.074	"		"	4.1735	105.128	401.55	3.81	
19	"	"	3.8162	112.685	"		"	4.1711	100.398	382.89	3.8	80% capacity cut-off is 93.1Ahr.
20	"	"	3.8142	108.488	"		"	4.1644	92.422	351.44	3.797	
21	"	"	3.8177	98.707	"		"	4.1495	77.564	293.59	3.77	End of test: Capacity return drops below 70%.
22												

NSWC-712 Rated Capacity;Ahr.:114.86

CHARGE (10 hour rate, except as noted)							DISCHARGE (6 hour rate except as noted)					Activated:
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARG RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	10hr.	4.0931	3.3818	114.86	RT		6hr.	4.062	111.6	432.21	3.86	Maccor doubled current on charge.
2	"	4.1073	3.775	"	"		"	4.076	114.62	444.13	"	ditto
3	"	4.1136	3.771	"	"		"	4.077	114.54	442.64	"	Normal charge
4	"	4.1196	3.771	"	"	50	"	4.078	114.49	441.82	3.85	
5	"	4.1241	3.775	"	"	65	"	4.079	113.06	436.12	"	
6	"	4.1329	3.779	"	"		"	4.013	114.33	441.23	"	
7	"	4.1322	3.779	"	"		"	4.067	115.15	444.69	"	
8	"	4.1273	3.774	"	"		"	4.083	114.45	442.03	"	
9	"	4.1302	3.774	"	"		"	4.084	114.18	441.05	"	
10	"	4.1352	3.776	"	"		"	4.088	113.8	439.54	"	
11	"	4.1407	3.776	"	"		"	4.089	113.75	439.30	"	
12	"	4.1422	3.777	"	"		"	4.09	113.29	437.43	"	
13	"	4.1388	3.778	"	"		"	4.027	113.23	437.17	"	
14	"	4.1348	3.775	"	"		"	4.086	112.65	434.83	"	
15	"	4.133	3.774	"	"		"	4.086	111.97	432.07	"	
16	"	4.133	3.776	"	"		"	4.086	111.06	428.43	"	
17	"	4.1354	3.779	"	"	73	"	4.088	109.95	424.05	"	
18	"	4.1388	3.784	"	"		"	4.092	109.02	420.43	"	
19	"	4.1433	3.786	"	"		"	4.096	107.85	415.80	"	
20		4.1529	3.791	"	"		"	4.104	107.15	413.05	"	
21		4.1629	3.797	"	"		"	4.114	106.48	410.33	"	
22		4.1732	3.8	"	"		"	4.122	105.03	404.54	3.845	
23		4.1882	3.801	"	"	77	"	4.133	102.73	395.38	3.84	80% eff.= 91.89Ah
24		4.2108	3.804	"	"	87d	"	4.154	95.4	366.20	3.83	2/13/77
25		4.2565	3.809	"	"		"					Charged 8Hr,9Min. then vented. Cell was shorted 51min. prior to
26			3.818									short.
27												
28												
29												
30												
31												
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% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC-713 Rated Capacity;Ah.:116.99

CHARGE (10 hour rate, except as noted)								DISCHARGE (6 hour rate except as noted)					Activated:1/22/97 Test start: 1/24/96 Soak: 47hrs.
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARGE RATE	OCV	AMP-HRS	RETURN Wh	PLATEAU VOLT.	REMARKS
1	10hr				RT		6hr		-			1st cycle charge and discharge would not accept load.Test stop.
2	"			125.91	"		"	4.0625	114.01	410.46	3.59	96 hours additional soak prior to restart.
3	"	4.3	3.782	15.18	"		"	-	15.02	52.71	3.52	40min. discharge.
4	40hr	"	-	81.87	"		"	3.951	-	81.39	3.57	40hr. charge, 6hr. discharge.
5	40hr	4.254	-	116.99	"		"	4.0715	115.85	413.46	3.55	
6		4.3	3.779	6.12	"		"	3.865	5.855	20.10	3.45	
7		"	3.805	47.81	"		"	3.91	47.032	163.81	3.42	
8		"	-	0.28	"		"	3.821	0.00126	0.00		
9		"	3.821	-	"		"	3.821	0.0286	0.09		17sec. discharge
10		"	3.82	-	"		"	3.82	0.004	0.01		2.6sec discharge.
11		"	"	0.004	"		"	3.82	0.002	0.01		1.3sec. discharge.
12		"	"	-	"		"	3.82	-	0.00		0.9sec. discharge
13		"	"	-	"		"	3.82	0.051	0.16		30sec. discharge.
14		"	"	11.78	"		"	3.88	12.45	42.55	3.43	2hr.40min. discharge
15		"	3.75	15.02	"		"	3.88	14.98	51.44	3.46	2hr.29min.discharge
16		"	3.74									
17												end of test 2/24/97
18												
19												
20												
21												

NSWC-714 Rated Capacity;Ah.:115.44

Activated:Feb.7,1997 Test Started: Feb.11,1997

CYCLE #	Time on Charge	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C) cell thermo	PRESSURE (PSIG)	DISCHARGE RATE	OCV	AMP-HRS	RETURN Wh	PLATEAU VOLT.	REMARKS
	CHARGE (10 hour rate, except as noted)						DISCHARGE (6 hour rate except as noted)					
1	28sec.	4.3	-	0.091	20.5 / 24		6hr	3.73	0.1357	0.43	3.1	Cell did not accept charge on 1st cycle.
2	10hr.	•	-	115.44	•	73 d	•	4.06	112.112	418.30	3.72	Cell temperature varied from 20.5C to 24C from beginning of life to
3	5:56	•	3.773	49.74	•	134 c	2hr.	3.91	38.48	142.19	3.7	end of life. The 44th cycle discharge increased cell temperature to
4	3:09	•	3.877	68.49	•	141 c	•	3.95	•	142.19	•	34C Room temperature varied from 17C to 19C.
5	8:06	•	3.9	36.38	•		•	3.94	•	143.57	3.72	
6	3:10	•	3.985	36.67	•		•	4.16	•	148.46	3.84	
7	3:27	•	3.979	39.84	•		•	4.17	•	148.62	3.85	
8	3:21	•	3.984	38.698	•	82 d	•	•	•	148.53	•	
9	•	•	•	38.71	•		•	•	•	148.12	3.84	
10	3:20	•	•	38.51	•		•	•	•	148.27	3.85	
11	•	•	•	38.47	•		•	•	•	148.43	•	
12	3:24	•	•	39.39	•		•	4.18	•	148.52	•	
13	3:19	•	3.986	38.35	•		•	•	•	148.25	3.845	
14	3:20	•	•	38.57	•		•	•	•	148.61	3.85	
15	3:21	•	•	38.78	•		•	•	•	147.73	•	
16	•	•	3.987	38.7	•		•	•	•	148.84	3.86	
17	3:19	•	•	38.38	•		•	•	•	148.79	3.85	
18	3:18	•	•	38.22	•		•	•	•	148.70	•	
19	3:20	•	3.985	38.5	•		•	•	•	148.72	•	
20	•	•	•	38.48	•		•	•	•	148.76	•	
21	3:21	•	•	38.7	•	123 c	•	•	•	148.80	•	
22	3:20	•	3.986	38.59	•		•	•	•	148.95	•	
23	3:19	•	•	38.4	•		•	•	•	148.87	•	
24	•	•	3.958	38.32	•		•	4.179	•	148.69	•	end voltage 3.78V
25	•	•	3.984	38.34	•	125 d	•	4.177	•	148.49	3.845	
26	•	•	3.983	38.28	•		•	4.176	•	148.66	3.86	
27	3:27	•	3.982	38.78	•		•	4.178	•	148.50	3.85	
28	3:18	•	3.983	38.12	•		•	4.175	•	148.37	3.845	
29	3:20	•	3.982	38.66	•	122 d	•	4.176	•	148.35	•	
30	3:19	•	•	38.43	•		•	4.175	•	148.25	3.84	end voltage 3.767V
31	3:21	•	3.981	38.67	•		•	•	•	148.19	•	
32	3:19	•	•	38.34	•		•	4.173	•	148.32	3.85	
33	3:24	•	3.98	39.29	•		•	4.177	•	148.45	3.845	
34	3:20	•	3.982	38.58	•	140 c	•	4.176	•	148.32	•	
35	3:19	•	•	38.31	•		•	4.173	•	148.15	•	end voltage 3.76V
36	3:21	•	3.98	38.71	•	128 d	•	4.174	•	148.37	3.85	
37	3:22	•	•	38.99	•		•	4.175	•	148.41	3.845	
38	3:24	•	3.981	39.25	•		•	4.18	•	148.61	3.85	
39	3:21	•	3.982	38.71	•		•	•	•	147.57	3.79	record#1971:current doubled when channel 4 was started.
40		•	•	6.759	•		•	4.01	•	144.30	3.74	end voltage 3.71V
41	:4	•	3.9	23.05	•	110 d	•	3.96	•	139.50	3.605	Terminated test to fix Maccor. end voltage 3.59V
42	:24	•	3.897	4.611	•		•	3.9	•	140.06	3.66	end voltage 3.19V
43	1:56	•	3.807	22.33	•		•	•	•	108.41	3.6	end voltage 1.188V
44	3:36	•	1.98	41.7	34C		•	3.93	•	129.82	•	1hr.45min., 33.87ah to 3.0V, end voltage 1.194V.
45			2.4	24.12			•	3.91	20.81	73.19	3.56	end voltage 3.0V
46												

% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC-715 Rated Capacity;Ahr.:117.66

CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C) test box	PRESSURE (PSIG)	DISCHARGE RATE	OCV	AMP-HRS	RETURN Wh	PLATEAU VOLT.	REMARKS
CHARGE (10 hour rate, except as noted)							DISCHARGE (6 hour rate except as noted)					Activated:1/31/97 Test Start:2/4/97 97hr soak
1	10hr.	4.1041		117.66	19		6hr.	4.0623	113.966	439.43	3.856	
2	"	4.1176		"	"	200 EOC	"	4.0779	117.396	453.12	3.85	
3	"	4.1251		"	"	186 EOC	"	4.0801	117.601	453.02	3.854	
4	"	4.1296		"	"	50 EOD	"	4.0807	117.417	451.67	3.84	
5	"	4.1333		"	"		"	4.0815	117.243	450.83	"	
6	"	4.1345		"	"		"	4.0828	116.198	446.74	"	
7	"	4.1398		"	"		"	4.0888	117.531	452.38	"	
8	"	4.1419		"	"		"	4.0895	117.283	451.33	"	
9	"	4.1477		"	"	153 EOC	"	4.0922	117.058	450.58	"	
10	"	4.1495		"	"		"	4.0931	117.127	450.82	"	
11	"	4.1471		"	"		"	4.0909	116.7	449.11	"	
12	"	4.1425		"	"	115 EOC	"	4.0874	115.88	445.87	"	
13	"	4.1331		"	"		"	4.0793	114.51	440.35	"	
14	"	4.1343		"	"		"	4.08	114.089	438.70	"	
15	"	4.1361		"	"	107 EOC	"	4.0813	112.917	434.00	"	
16	"	4.1326		"	"		"	4.0797	112.305	431.94	"	
17	"	4.1343		"	"		"	4.0819	111.678	429.11	"	
18	"	4.1364		"	"		"	4.0834	110.334	423.51	"	
19	"	4.1396		"	"		"	4.0856	108.785	417.43	3.83	
20	"	4.1484		"	"	0	"	4.0909	107.031	410.40	"	
21	"	4.1581		"	"	"	"	4.1012	105.96	408.13	"	90% cycling Eff.=105.89Ahr.
22	"	4.1651		"	"	"	"	4.1072	103.42	395.85	3.82	
23	"	4.1764		"	"	"	"	4.1153	97.82	373.50	"	
24	"	4.1358		"	"	"	"	4.1616	87.81	333.93	3.8	80% cycling Eff.= 92.72Ahr.
25	"	4.3		111.649	"	"	"	4.2488	73.296	278.58	3.8	9hr. const.current +1hr.const. voltage charge
26												End of Test
27												Note: Examination of cell after test revealed a vertical weld seam
28												on the side of the case had releaved and exposed cell stack. This
29												caused electrolyte leakage and stack drying. Deep drawn steel
30												cases would eliminate this problem in addition to saving weight
31												
32												

EOC = end of charge
EOD = end of discharge

NSWC-716 Rated Capacity;Ahr.100.

Activated: Test Started: 10/15/97

CHARGE (10 hour rate, except as noted)							DISCHARGE (6 hour rate except as noted)						
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARG RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	30 hr	4.038	3.353	100	RT		6 hr	4.014	96.755	366.0	3.78	Pos. Post was repaired and is high resistance
2	30 hr	4.054	3.788	36+63.	25C		•	4.029	99.96	378.8	3.785	
3	10 hr	4.118	3.784	100	•		•	4.027	33.33	127.7	3.863	2 hr. Discharge
4	•	4.148	3.923	33	•		•	4.025	33.33	127.3	3.81	
5	•	4.155	3.921	•	•		•	4.024	33.33	127.0	3.8	
6	•	4.143	3.921	•	•		•	4.02	33.33	126.7	3.79	
7	•	4.152	3.918	•	•		•	4.02	33.33	126.6	3.79	
8	•	4.165	3.917	•	•		•	4.014	33.33	126.7	3.8	
9	•	4.155	4.03	•	•		•	4.014	33.33	126.2	3.78	
10	•	4.164	3.918	•	•		•	4.013	33.33	126.2	3.78	
11	•	4.129	3.917	•	•		•	4.009	33.33	126.1	3.78	
12	•	4.121	3.914	•	•		•	4.008	33.33	126.3	3.785	
13	•	4.119	3.914	•	•		•	4.009	33.33	126.1	3.78	
14	•	4.121	3.915	•	•		•	4.008	33.33	125.4	3.76	
15	•	4.117	3.914	•	•		•	4.004	33.33	126.0	3.77	
16	•	4.101	3.91	•	•		•	4.004	33.33	125.7	3.77	
17	•	4.104	3.91	•	•		•	4	33.33	125.8	3.77	
18	•	4.105	3.912	•	•		•	4.001	33.33	125.7	3.77	
19	•	4.101	3.912	•	•		•	3.998	33.33	125.5	3.76	
20	•	4.1	3.91	•	•		•	3.998	33.33	125.7	3.77	
21	•	4.095	3.908	•	•		•	3.996	33.33	125.2	3.75	
22	•	4.122	3.91	•	•		•	3.999	33.33	125.5	3.76	
23	•	4.104	3.91	•	•		•	3.994	33.33	125.0	3.75	
24	•	4.102	3.905	•	•		•	3.989	33.33	124.5	3.735	
25	•	4.11	3.904	•	•		•	3.984	33.33	124.8	3.75	
26	•	4.112	3.905	•	•		•	3.994	33.33	124.6	3.74	
27	•	4.116	3.909	•	•		•	3.993	33.33	123.73	3.71	
28	•	4.128	3.908		•		•	3.989	33.33	124.32	3.725	
29	•	4.11	3.908		•		•	3.987	33.33	124.93	3.75	
30	•	4.108	3.905		•		•	3.985	33.33	124.50	3.74	
31	•	4.099	3.908		•		•	3.983	33.33	124.77	3.74	
32	•	4.101	3.905		•		•	3.986	33.33	124.41	3.73	
33	•	4.095	3.904		•		•	3.977	33.33	124.16	3.715	
34	•	4.099	3.902		•		•	3.974	33.33	123.75	3.716	
35	•	4.104	3.903		•		•	3.973	33.33	124.22	3.728	
36	•	4.099	3.903		•		•	3.971	33.33	123.90	3.723	
37	•	4.085	3.903		•		•	3.971	33.33	124.73	3.737	
38	•	4.086	3.903		•		•	3.969	33.33	124.14	3.715	
39	•	4.087	3.904		•		•	3.968	33.33	124.48	3.738	
40	•	4.078	3.904		•		•	3.966	33.33	123.36	3.69	
41	•	4.101	3.903		•		•	3.964	33.33	123.82	3.71	
42	•	4.078	3.901		•		•	3.96	33.33	123.87	3.716	
43	•	4.076	3.901		•		•	3.958	33.33	124.35	3.73	
44	•	4.074	3.901		•		•	3.958	33.33	123.32	3.69	
45	•	4.078	3.901		•		•	3.954	33.33	123.4	3.69	
46	•	4.076	3.9		•		•	3.951	33.33	124.1	3.725	
47	•	4.062	3.898		•		•	3.948	33.33	123.73	3.715	
48	•	4.084	3.897		•		•	3.948	33.33	123.38	3.71	
49	•	4.084	3.899		•		•	3.946	33.33	123.3	3.7	
50	•	4.068	3.896		•		•	3.94	33.33	123.46	3.7	

% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC-716 Rated Capacity;Ahr.100.

Activated: Test Started: 10/15/97

CYCLE #	CHARGE (10 hour rate, except as noted) RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARGE (6 hour rate except as noted) DISCHARG RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
51	10 hr.	4.058	3.892	•	•		•	3.937	33.33	123.27	3.7	2hr. discharge
52	10 hr.	4.06	3.889	•	•		•	3.936	33.33	123.86	3.72	
53	10 hr.	4.06	3.894	•	•		•	3.939	33.33	123.52	3.71	soft shorts
54	10 hr.	4.049	3.894	•	•		•	3.934	33.33	123.28	3.71	
55	10 hr.	4.048	3.89	•	•		•	3.929	33.33	122.58	3.68	
56	10 hr.	4.052	3.884	•	•		•	3.929	33.33	122.85	3.68	
57	10 hr.	4.055	3.884	•	•		•	3.932	33.33	122.78	3.68	
58	10 hr.	4.048	3.887	•	•		•	3.932	33.33	123.08	3.687	
59	10 hr.	4.053	3.884	•	•		•	3.932	33.33	122.7	3.67	3.848v @2hr., soft shorts
60	10 hr.	4.066	3.882	•	•		•	3.929	33.33	122.85	3.68	
61	10 hr.	4.075	3.879	•	•		•	3.932	33.33	122.48	3.68	
62	10 hr.	4.061	3.875	•	•		•	3.929	33.33	122.57	3.68	
63	10 hr.	4.053	3.873	•	•		•	3.928	33.33	122.6	3.68	
64	10 hr.	4.058	3.869	•	•		•	3.928	33.33	122.68	3.68	
65	10 hr.	4.058	3.863	•	•		•	3.927	33.33	122.52	3.68	
66	10 hr.	4.048	3.855	•	•		•	3.925	33.33	122.41	3.68	3.65v @2hr.
67	10 hr.	4.063	3.842	•	•		•	3.924	33.33	121.96	3.678	
68	10 hr.	4.061	3.822	•	•		•	3.922	33.33	120.82	3.645	2.84v @2hr.
69	10 hr.	4.058	3.774	•	•		•	3.92	33.33	118.57	3.65	1.749v @2hr.
70	10 hr.	4.057	2.917	•	•		•	3.923	33.33	112.75	3.65	1.26v @2hr.
71	10 hr.	4.052	2.097	•	•		•	3.922	33.33	105.59	3.6	1.16v @2hr.
72	10 hr.	4.059	1.929	•	•		•	3.919	33.33	99.62	3.58	1.13v @2hr.
73	10 hr.	4.073	1.889	•	•		•	3.924	33.33	93.02	3.54	0.93v @2hr.
74	10 hr.	4.108	1.879	•	•		•	3.937	33.33	82.84	3.3	0.271v@2hr.
75	10 hr.		1.65	•	•		•					End of Test
76	10 hr.											
77	10 hr.											
78	10 hr.											
79	10 hr.											
80												

NSWC-717 Rated Capacity;Ahr.:109.4 Test channel #4

CHARGE (10 hour rate, except as noted)							DISCHARGE (6 hour rate except as noted)					BASELINE TEST Activated:2/17/09 88 hour soak
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARG RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	10Hr.	4.095	3.924	44.74	RT		6Hr.	4.065	107.89	417.80	3.86	current doubling on charge.
2	"	4.101	3.7724	109.4	"		"	4.071	108.86	421.38	"	current doubling on charge and disharge.
3	"	4.106	3.7796	"	"		"	4.073	109.03	421.60	"	
4	"	4.113	3.7823	"	"		"	4.075	108.63	411.52	3.855	
5	"	4.128	3.7864	"	"		"	4.087	111.183	429.23	3.85	
6	"	4.115	3.7735	"	"		"	4.075	109	420.65	"	
7	"	4.111	3.7694	"	"		"	4.073	108.87	420.42	"	
8	"	4.111	3.7694	"	"		"	4.073	108.46	418.92	"	
9	"	4.114	3.7763	"	"		"	4.052	108.22	417.99	"	
10	"	4.118	3.7709	"	"		"	4.077	107.97	417.00	"	
11	"	4.119	3.7711	"	"		"	4.077	107.2	413.90	"	
12	"	4.121	3.7712	"	"		"	4.079	107.78	416.20	"	
13	"		3.7697	104.49	"		"					At 9hr.13min. into charge the cell shorted. After 30 min. with
14												voltage fluxuations from 0.256V to 5.11V the cell vented.
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% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC-718 Rated Capacity;Ahr.: 108.695

CHARGE (10 hour rate, except as noted)							DISCHARGE (6 hour rate except as noted)					Activated:
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARG RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	10.0 hrs	4:1250	3.4136	0.2060				3.7471	0.1535	0.490		
2	10.0 hrs	4.1250	3.3986	5.60198	•			3.8710	3.1917	11.140		10.0 min. discharge.
3	•	•	3.8125	9.85875	•			3.8899	9.37115	33.566		31.0 min.discharge.
4	2.0 hrs	4.1650	3.8324	108.1630	•			4.0732	108.4400	399.770	3.670	
5	10.0 hrs	4.1250	3.7828	38.4950	•			3.9160	38.5001	140.320	3.660	3.0 hrs. 32.0 min. charge.
6	20.0 hrs	4.1650	3.8160	107.2590	•			4.0679	70.4894	260.850		3.0 hrs. 53.0 min. discharge. 19.0 hrs. 44.0 min charge.
7	20.0 hrs	4.1650	3.9045	74.9360	•			4.0905	111.4400	414.080	3.710	6.0 hrs. 9.0 min. discharge. 13.0 hrs. 47.0 min. charge.
8	20.0 hrs	4.1383	3.7819	108.6950	•			4.0773	108.6460	402.790	3.696	6.0 hrs. discharge.
9	10.0hrs	4.1650	3.7834	100.6410	•			4.0399	100.3060	371.480	3.700	
10	10.0 hrs	4.1650	3.7827	100.3630	•			4.0413	100.2710	371.070	3.695	9.0 hrs. 14.0 min. charge. 5.0 hrs. 32.0 min. discharge.
11	10.0 hrs	•	3.7834	98.7050	•			4.0341	98.5030	363.450	3.690	9.0 hrs. 4.0 mins. charge.
12	10.0 hrs	•	3.7840	97.8468	•			4.0345	97.4179	359.410	3.690	9.0 hrs. 0.0 min. charge. 5.0 hrs. 22.0 min. discharge.
13	•	•	3.7850	98.0100	•			4.0336	97.4177	359.050	3.680	
14	•	•	3.7865	96.5017	•			4.0286	95.8290	352.850	3.680	
15	•	•	3.7878	94.6830	•			4.0224	94.0164	345.960	3.680	
16	•	•	3.7895	93.0970	•			4.0169	92.2380	338.790	3.670	
17	•	•	3.7916	90.3630	•			4.0076	89.3049	327.580	3.670	8.0 hrs. 18.0 min. charge. 4.0 hrs. 55.0 min. discharge.
18	•	•	3.7926	87.6730	•			3.9994	86.2406	316.460	3.670	8.0 hrs. 3.0 min.
19	•	•	3.7964	87.4410	•			4.0019	85.8730	314.230	3.670	
20	•	•	3.7948	84.6360	•			3.7939	82.9450	303.700	•	7.0 hrs. 47.0 min. charge. 3.0 hrs. 32.0 min. discharge.
21	•	•	3.7920	85.6250	•			3.9988	83.6280	305.730	3.660	7.0 hrs. 52.0 min. charge. 4.0 hrs. 38.0 min. discharge.
22	•	•	3.7912	79.2880	•			3.9797	76.9430	281.060	3.670	
23	•	•	3.7919	80.7660	•			3.9861	77.9050	285.050	3.670	
24	•	•	3.7922	81.1940	•			3.9883	77.9816	285.150	3.670	
25	•	•	3.7936	59.8150	•			3.9391	58.8718	214.150	3.660	
26	•	•	3.7908	61.0630	•			3.9421	58.3910	212.330	•	
27	•	•	3.7917	52.8266	•			3.9324	50.3165	182.170	3.640	
28	•	•	3.7945	31.1460				3.9122	30.8570	11.610	•	
29	•	•	3.7892	9.5810				3.8920	9.7400	34.670	3.600	
30	•	•	3.7876	9.4330				3.8920	9.2570	32.840	•	
31	•	•	3.7861	15.5960				3.9018	14.8680	53.230	•	
32	•	•	3.7857	11.5360				3.8867	11.0470	78.412	•	
33	•	•	3.7852	22.4500				3.9076	21.0700	75.808	3.620	
34	•	•	3.7867	23.6620				3.9086	22.2190	79.98	3.620	
35	•	•	3.7883	16.4760				3.9040	15.6130	55.847	3.610	end of test
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% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC-719 Rated Capacity;Ahr.:110.18

CHARGE (10 hour rate, except as noted)							DISCHARGE (6 hour rate except as noted)					Activated:3/10/97 Start: 3/13/97 72 hours soak
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARG RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	20 hr	4.0785	3.4106	110.18	17	225c	6hr	4.0599	107.293	414.6	3.86	
2	"	4.0922	3.777	"	"		"	4.0735	110.114	425.4	3.85	
3	10 hr	4.1107	3.777	"	"		"	4.0739	110.07	424.8	3.85	
4	"	4.1162	3.775	"	"		"	4.075	109.651	422.3	3.84	
5	"	4.1236	3.774	"	18		"	4.0783	108.645	418.0	3.84	
6	"	4.1307	3.7814	"	"		"	4.0845	111.191	428.1	3.84	
7	"	4.1236	3.7753	"	"		"	410.783	109.907	423.1	3.84	
8	"	4.1249	3.7739	"	"		"	4.0798	109.311	413.1	3.94/3.78	37A Current doubles 8cycle charge/discharge, 18A/37A
9	"	4.1293	3.774	"	"		"	4.0837	109.882	419.9	3.84	Current doubles, Charge
10	"	4.1275	3.7746	"	"		"	4.0809	109.311	421.1	3.84	
11	"	4.128	3.7741	"	"		"	4.0814	109.22	420.8	3.84	
12	"	4.128	3.7733	"	"		"	4.0808	109.05	419.9	3.84	
13	"	4.1269	3.7716	"	"		"	4.0798	108.707	418.7	3.84	
14	"	4.1259	3.7707	"	"		"	4.079	108.478	417.8	3.84	
15	"	4.124	3.7702	"	"		"	4.0778	108.132	416.4	3.84	
16	"	4.1225	3.7695	"	"		"	4.0765	107.6	414.1	3.84	
17	"	4.1271	3.7693	"	"		"	4.0761	106.901	411.4	3.84	
18	"	4.1219	3.77	"	"		"	4.076	105.994	407.8	3.84	
19	"	4.1243	3.7722	"	"		"	4.078	105.08	404.2	3.84	
20	"	4.1288	3.777	"	"		"	4.0819	104.162	400.8	3.84	
21	"	4.134	3.7819	"	"		"	4.0865	103	396.0	3.84	
22	"	4.1426	3.7862	"	"		"	4.0942	101.837	391.6	3.84	
23	"	4.1539	3.7902	"	"		"	4.1042	100.509	386.4	3.84	
24	"	4.1649	3.7944	109.519	"		"	4.1135	98.299	377.8	3.84	
25	"	4.165	3.7999	106.79	"		"					short indicated on OCV after charge then vented at start of
26												discharge.
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% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC-720 Rated Capacity;A 109.2

	CHARGE (10 hour rate, except as noted)						DISCHARGE (6 hour rate except as noted)					Activated:
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARG RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	20 hr.	4.078	3.3526	109.2			6	4.0589	106.004	409.0	3.85	5hrs. 49 min. dishcarge 20hr. charge
2	20 hr.	4.0921	3.7815	109.2			6	4.0713	108.72	419.2	3.84	6 hr. discharge
3	10 hr.	4.1123	3.7793	109.2			6	4.0731	72.463	281.8	3.87	10 hr. charge 6hr. discharge for 4hr. then
4	10 hr.	4.165	3.9098	81.619			6	4.1236	72.463	283.2	3.88	4hr. discharge
5	10 hr.	4.165	3.9074	72.433			6	4.1224	72.463	282.9	3.88	
6	10 hr.	4.165	3.907	72.33			6	4.1208	72.4626	284.6	3.88/3.82	current doubling end of charge/all of discharge
7	10 hr.	4.165	3.9065	72.327			6	4.1191	72.4621	285.0	3.88/3.82	current doubling ,
8	10 hr.	4.165	3.9063	72.543			6	4.1173	72.463	283.3	3.87	current doubling for 40 min.
9	10 hr.	4.165	3.9614	71.869			6	4.1158	72.463	296.5	3.878/3.81	current doubling charge and discharge
10	10 hr.	4.165	3.906	72.3372			6	4.114	72.463	281.9	3.868	current doubling 2880 charge records
11	10 hr.	4.165	3.9054	71.76			6	4.111	72.463	281.6	3.86	
12	10 hr.	4.165	3.9048	71.65			6	4.1091	72.463	281.5	3.86	
13	10 hr.	4.165	3.9545	72.125			6	4.1076	72.463	281.5	3.86	
14	10 hr.	4.165	3.9047	73.3187			6	4.1081	72.462	281.7	3.86	
15	10 hr.	4.165	3.9048	73.564			6	4.1086	72.463	281.9	3.87	
16	10 hr.	4.165	3.9049	73.342			6	4.1065	72.463	282.0	3.876	
17	10 hr.	4.165	3.9051	73.253			6	4.1078	72.463	282.0	3.87	
18	10 hr.	4.165	3.9052	73.398			6	4.1076	72.462	282.0	3.87	
19	10 hr.	4.165	3.9048	73.584			6	4.1033	72.462	281.9	3.87	
20	10 hr.	4.165	3.9051	73.655			6	4.1065	72.463	281.8	3.87	Doubling on charge 1hr. 45min.
21	10 hr.	4.165	3.9051	73.886			6	4.1062	72.463	281.8	3.876	Doubling on Discharge, 7min. 46sec.
22	10 hr.	4.165	3.9049	74.085			6	4.1059	72.463	281.5	3.87	
23	10 hr.	4.165	3.9044	74.398			6	4.1059	72.463	279.7	3.84/3.77	Doubled on Discharge 2hr.
24	10 hr.	4.165	3.9037	74.353			6	4.106	72.463	275.8	3.86/3.80	Doubled on Charge and Discharge 100%
25	10 hr.	4.165	3.9028	75.879			6	4.1067	72.463	275.7	3.86/3.80	Doubled on Charge and Discharge 100%
26	10 hr.	4.165	3.9021	75.804			6	4.1068	72.463	279.9	3.86	1hr. of doubling 2 min. discharge
27	10 hr.	4.165	3.9017	76.3479			6	4.1072	72.463	281.10	3.86	3.81v at end of discharge
28	10 hr.	4.165	3.9012	76.273			6	4.1069	72.463	281.00	3.856	3 hr. doubling during charge
29	10 hr.	4.165	3.9005	76.735			6	4.1068	72.463	280.86	3.856	)
30	10 hr.	4.165	3.8995	76.744			6	4.106	72.463	280.68	3.855	double on charge 5 hr. 22min.
31	10 hr.	4.165	3.8985	77.317			6	4.1056	72.463	280.46	3.855	
32	10 hr.	4.165	3.8966	77.63			6	4.105	72.463	280.17	3.855	
33	10 hr.	4.165	3.8942	78.427			6	4.104	72.463	279.86	3.85	
34	10 hr.	4.165	3.891	78.2321			6	4.1023	13.419	55.49		doubled current charge and discharge
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36												Cell vented after 44min. in discharge
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% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC-721 Rated Capacity;Ahr.112.67

	CHARGE (10 hour rate, except as noted)						DISCHARGE (6 hour rate except as noted)					Activated:3/25/97
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARG RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	20 hr	4.3	3.3922	63.97			6 hr	3.9207	60.94	223.2	3.61	Charged in 11hr. 21min. to 4.3V
2	10 hr	4.3	3.78	94.77			20 hr	3.995	94.77	357.6	3.76	Discharged for 18hr. 49min. to 3V
3	10 hr	4.287	3.508	112.66			20 hr	4.066	103.37	388.3	3.73	Discharged for 18hr. 21min. to 3V
4	10 hr	4.3	3.426	32.88			20 hr	3.894	24.61	91.7		Short vent
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% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC-722 Rated Capacity;Ahr.:107.55

	CHARGE (10 hour rate, except as noted)						DISCHARGE (6 hour rate except as noted)					Activated:
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARG RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	20 hr	4.093	3.35	107.55	RT		6 hr	4.074	104.804	405.6	3.868	Baseline Cycle
2	•	4.109	3.778	•	•		•	4.088	107.35	415.8	3.86	
3	10 hr	4.13	3.776	•	•		•	4.089	71.7	280.1	3.887	3.84V end voltage discharge 4hrs.
4	•	4.166	3.904	77.436	•		•	4.121	71.7	281.0	3.897	3.841V end voltage discharge 4hrs.
5	•	•	3.904	71.497	•		•	4.118	71.7	280.7	3.89	
6	•	•	3.904	71.603	•		•	4.114	71.7	280.3	3.886	3.834V end voltage discharge 4hrs.
7	•	•	3.902	71.53	•		•	4.114	71.7	280.1	3.88	3.831V end voltage discharge 4hrs.
8	•	•	3.902	72.03	•		•	4.112	71.7	280.1	3.88	3.831V end voltage discharge 4hrs.
9	•	•	3.902	72.14	•		•	4.114	71.7	280.1	3.88	3.831V end voltage discharge 4hrs.
10	•	•	3.903	71.78	•		•	4.113	59.429	233.3	3.88	3hrs. 19min. on discharge, plug on recorder jumpered
11	•	•	3.909	59.864	•		•	4.111	71.7	280.0	3.88	
12	•	•	3.901	72.158	•		•	4.113	71.7	280.1	3.88	4hr discharge
13	•	2.371	3901	19.1	•		•					Test ended 04/17/97
14												cell vented
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% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC-723 Rated Capacity;Ahr.:106.5

Activated:4/13/97 5pm Start: 4/17/97 91 hour soak

	CHARGE (10 hour rate, except as noted)						DISCHARGE (8 hour rate except as noted)					
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARG RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	20 hr	4.058	3.386	106.5	RT		8 hr	4.038	104.183	401.9	3.858	
2	20 hr	4.07	3.782	•	•		•	4.051	106.824	411.8	3.858	
3	10 hr	4.084	3.781	•	•		•	4.048	106.28	409.1	3.85	
4	•	4.09	3.78	•	•		•	4.049	106.123	408 0	3 84	
5	•	4.098	3.774	•	•		•	4.049	106.104	407.8	3.84	
6	•	4.098	3.78	•	•		•	4 052	105.921	408.9	3.84	
7	•	4.059	3.777	•	•		•	4.053	106 687	410 2	3 84	
8	•	4.098	3.773	•	•		•	4.05	105.99	407 5	3.84	
9	•	4.098	3.774	•	•		•	4.052	105 9	407.3	3.84	
10	•	4.101	3.774	•	•		•	4 055	105.76	406 8	3 84	
11	•	4.104	3.778	•	•		•	4 058	105.57	406 0	3 84	
12	•	4.102	3.778	•	•		•	4.054	105.31	404 8	3.84	
13	•	4.104	3.775	•	•		•	4.104	105.04	403.9	3.84	
14	•	4.105	3.772	•	•		•	4.057	104.58	402.2	3 84	
15	•	4.105	3.778	•	•		•	4 058	104.29	400.9	3 84	
16	•	4.107	3.778	•	•		•	4.057	104 02	399.9	3 84	
17	•	4.108	3.775	•	•		•	4.058	103.28	398 6	3 84	
18	•	4.107	3.777	•	•		•	4.057	102.55	394 0	3.84	
19	•	4.109	3.781	•	•		•	4.062	101.81	391.1	3 84	
20	•	4.11	3 783	•	•		•	4.064	100.75	386 9	3 84	
21	•	4.115	3.787	•	•		•	4.067	99.698	382.7	3 84	
22	•	4.125	3.789	•	•		•	4.077	99.04	380.4	3 84	
23	•	4.133	3.785	•	•		•	4.083	97.88	376.0	3.84	
24	•	4.144	3.802	•	•		•	4.092	95.71	367.5	3 84	
25	•	4.163	3.808	•	•		•	4.112	96 62	371 3	3 84	
26	•	1.069	3.808	•	•		•	1.123				42 minutes shorted on charge, cell vented
27												
28												
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% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC-724 Rated Capacity;Ahr.:92.6

Activated:4/18/97 Start: 4/23/97 113hr. soak

CHARGE (10 hour rate, except as noted)							DISCHARGE (6 hour rate except as noted)					
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARG RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	20 hr	4.03	3.38	92.6	RT		6 hr	4.015				
2				•	•							
3				•	•							
4				•	•							
5				•	•							
6				•	•							
7				•	•							
8				•	•							
9	10 hr	4.052		•	•		20 hr	4.016	89.06	347.3		
10	•			•	•		•					
11	•			•	•		•					
12	•			•	•		•					
13	•			•	•		•					
14	•			•	•		•					
15	•			•	•		•					
16	•			•	•		•					
17	•			•	•		•					
18	•			•	•		•					
19	•			•	•		•		59.4	225.1		4.63Amp Discharge test end 5/16/97
20	•			•	•		•					
21	•			•	•		•					
22	•			•	•		•					
23	•			•	•		•					
24	•			•	•		•					
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% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC-725 Rated Capacity;Ahr.:108.3

CHARGE (10 hour rate, except as noted)							DISCHARGE (6 hour rate except as noted)					Activated: Start: 5/2/97
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARG RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	20 hr	4.06	3.417	108.3	RT		6 hr	4.045	102.8	395.6	3.845	Changed file to NSWC 725A
2	•	4.087	3.781	•	•		•	4.074	107.9	415.8	3.845	
3	•	4.095	3.778	•	•		•	4.082	109.02	420.0	3.845	
4	•	4.098	3.781	•	•		•	4.084	109.13	420.2	3.84	
5	•	4.1	3.781	•	•		•	4.084	109.29	420.7	3.84	
6	•	4.105	3.783	•	•		•	4.088	109.09	419.9	3.84	
7	•	4.106	3.793	•	•		•	4.089	108.65	417.9	3.84	
8	•	4.111	3.788	•	•		•	4.094	110.38	424.4	3.84	
9	•	4.108	3.782	•	•		•	4.089	109.42	420.1	3.83	
10	•	4.108	3.78	•	•		•	4.089	109.56	420.2	3.83	
11	•	4.106	3.773	•	•		•	4.087	109.52	420.1	3.83	
12	•	4.106	3.776	•	•		•	4.084	109.38	419.1	3.83	
13	•	4.105	3.776	•	•		•	4.083	110.05	421.0	3.82	
14	•	4.103	3.773	•	•		•	4.08	108.45	414.7	3.82	
15	•	4.105	3.779	•	•		•	4.083	108.61	415.1	3.82	
16	•	4.102	3.779	•	•		•	4.08	108.76	415.9	3.82	
17	•	4.101	3.779	•	•		•	4.08	108.44	415.0	3.827	
18	•	4.099	3.778	•	•		•	4.079	107.42	411.4	3.83	
19	•	4.095	3.784	•	•		•	4.075	105.82	405.3	3.83	
20	•	4.098	3.792	•	•		•	4.097	105.35	403.6	3.83	
21	•	4.095	3.789	•	•		•	4.074	104.67	401.0	3.83	
22	•	4.087	3.786	•	•		•	4.068	103.1	394.9	3.83	
23	•	4.082	3.783	•	•		•	4.063	100.51	384.5	3.83	
24	•	4.069	3.783	•	•		•	4.048	96.37	368.3	3.82	
25	•	4.06	3.783	•	•		•	4.041	93.77	357.9	3.818	
26	•	4.06	3.783	•	•		•	4.04	92.68	353.5	3.816	
27	•	4.058	3.7863	•	•		•	4.037	90.58	345.32	3.816	
28	•	4.045	3.785	•	•		•	4.023	86.03	326.98	3.8	
29	•	4.043	3.78	•	•		•	4.018	82.55	312.82	3.785	
30	•	4.063	3.786	•	•		•	4.035	80.08	302.49	3.76	Discharge time 4hr 28 min.
31	•	4.103	3.802	•	•		•	4.071	79.38	299.67	3.75	Discharge time 4 hr 23 min.
32	•	4.149	3.814	•	•		•	4.113	74.92	282.27	3.72	Discharge time 4hr 9 min.
33												End of Test by Cap. return 75.81Ah
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% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC-726 Rated Capacity;Ahr.:110.78

CHARGE (10 hour rate, except as noted)							DISCHARGE (6 hour rate except as noted)					Activated:
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARG RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	20 hr	4.072	3.41	110.78	RT		6 hr	4.051	105.8	404.2	3.848	5hr. 41min.
2	20 hr	4.101	3.763	•	•		•	4.08	110.19	424.2	3.845	6hr.
3	10 hr	4.124	3.778	•	•		•	4.124	110.23	424.2	3.845	
4	•	4.13	3.78	•	•		•	4.084	110.4	424.0	3.835	
5	•	4.133	3.779	•	•		•	4.086	110.06	422.1	3.831	
6	•	4.135	3.778	•	•		•	4.084	110.57	423.7	3.83	
7	•	4.131	3.778	•	•		•	4.082	110.47	423.5	3.83	
8	•	4.134	3.774	•	•		•	4.087	110.22	423.1	3.835	
9	•	4.134	3.773	•	•		•	4.086	110.42	424.1	3.83	
10	•	4.135	3.774	•	•		•	4.088	109.56	420.6	3.835	
11	•	4.149	3.774	•	•		•	4.091	109.24	419.2	3.835	
12	•	4.144	3.777	•	•		•	4.088	109.05	418.2	3.835	
13	•	4.134	3.773	•	•		•	4.084	108.79	417.8	3.835	
14	•	4.127	3.778	•	•		•	4.079	108	414.7	3.835	
15	•	4.127	3.779	•	•		•	4.077	107.53	412.9	3.835	
16	•	4.123	3.781	•	•		•	4.073	106.27	407.9	3.83	
17	•	4.125	3.778	•	•		•	4.076	105.14	403.4	3.83	
18	•	4.127	3.778	•	•		•	4.076	103.35	398.0	3.83	
19	•	4.132	3.781	•	•		•	4.078	101.54	388.8	3.825	
20	•	4.14	3.785	•	•		•	4.085	100.11	383.1	3.825	
21	•	4.15	3.789	•	•		•	4.092	98.62	377.2	3.817	
22	•	4.165	3.792	•	•		•	4.102	97.13	370.9	3.81	
23	•	4.165	3.796	106.18	•		•	4.099	90.81	345.9	3.778	
24	•	4.165	3.805	101.78	•		•	4.091	81.02	307.0	3.765	
25	•	4.165	3.82	87.7	•		•	4.08	64.7	243.3	3.63	end of test below 70% of rated capacity 06/02/97
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% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC-727 Rated Capacity;Ahr.: 88.3

	CHARGE (10 hour rate, except as noted)						DISCHARGE (6 hour rate except as noted)					Activated:
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARG RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	20.0 hrs	4.040	3.3830	88.30			6.0 hrs.	3.998	85.3	319.90	3.75	
2					•							
3	•	•			•							
4					•							
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12		•			•							
13	•	•			•							
14	•	•			•							
15	10.0 hrs.	4.123		88.30	•			4.014	87.3	323.14	3.70	
16	•	•			•							
17	•	•			•							
18	•	•			•							
19	•	•			•							
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25	•	•			•							
26	•	•			•							
27	•	•			•							
28	•	•										
29	•	•							65.42	238.80		
30	8.8 hrs.	•					10.0 hrs.		59.37	215.87		4.0 hrs. 1.0 min. DISCHARGE -Vent.
31	•	•										
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% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC-728 Rated Capacity;Ahr.:100

CHARGE (10 hour rate, except as noted)							DISCHARGE (6 hour rate except as noted)					Activated:
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARG RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	10 hr	4.068	3.365	109	RT		6	4.033	163.515	479.2	see curve	Discharged 9 hours then 15 days ocv
2	10 hr	4.3	2.161	28.14	RT		6	3.845	2.58	8.6	3.85	
3	•			•	•							Discharged 9hr. to 1.045v
4	•			•	•							
5	•			•	•							
6	•			•	•							
7	•			•	•							
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% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC-728 Rated Capacity:A hr: 112.6

	CHARGE (10 hour rate, except as noted)						DISCHARGE (6 hour rate except as noted)					Activated:
CYCLE #	RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARG RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	10	4.3	3.449		28F	60						
2	10	4.225	3.45									2.8 sec. Charge
3	10	4.188										2.3 sec. Charge
4	10	4.1	3.48									25 sec. Charge
5	1A	4.229	3.594									5 min.
6	1A	4.196		112.6				4.043	95.54	358.2	3.73	112 hr. 33 min. Charge
7	11.2A	4.272	3.815	0.012	28F							
8	1A	4.2						4.104	105.16	387.2		
9	1A			112.6	RT				18.36	66.1		
10	11.26A	4.167	3.821	17.71				4.128	102.48	377.6		
11	1A	4.14		112.8					99.01	365.8	3.68	
12	.5A	4.132		112.6								
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% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

NSWC-730 Rated Capacity;Ahr.:112.16

Activated:9/12/97 Test Start: 9/16/97

CYCLE #	CHARGE (10 hour rate, except as noted) RATE	CUTOFF VOLT.	OCV	AMP-HRS	TEMP.(°C)	PRESSURE (PSIG)	DISCHARGE (6 hour rate except as noted) DISCHARG RATE	OCV	AMP-HRS	RETURN Whr.	PLATEAU VOLT.	REMARKS
1	20 hr.	4.091	3.349	112.13	RT	60	6 hr.	4.064	109.08	425.5	3.86	
2	"	4.099	3.757	112.13	"	60	6 hr.	4.077	112.24	434.7	3.86	
3	10 hr.	4.118	3.817	112.13	"	60	6 hr.	4.071	109.17	422.2	3.86	28F Discharge
4	10 hr.	4.133	3.863	112.13	RT ch 28	60	6 hr.	4.085	111.82	432.5	3.86	
5	10 hr.	4.136	3.859	112.13	"	60	6 hr.	4.086	113.89	439.4	3.846	
6	10 hr.	4.128	3.769	112.13	"	60	6 hr.	4.075	111.5	429.9	3.845	
7	10 hr.	4.13	3.77	112.13	RT	60	6 hr.	4.078	111.7	431.1	3.845	
8	10 hr.	4.129	3.768	112.13	"	60	6 hr.	4.081	111.93	432.0	3.845	
9	10 hr.	4.132	3.765	112.13	"	60	6 hr.	4.082	111.87	431.9	3.845	
10	10 hr.	4.133	3.762	112.13	"	60	6 hr.	4.079	111.52	430.4	3.845	
11	10 hr.	4.141	3.825	112.13	RT ch 28	60	6 hr.	4.083	109.05	42.9	3.845	
12	10 hr.	4.152	3.865	112.13	RT	60	6 hr.	4.096	114.02	440.9	3.85	
13	10 hr.	4.145	3.821	112.13	28F	60	6 hr.	4.065	109.11	420.8	3.845	28F Discharge
14	10 hr.	4.171	3.856	112.13	28F	60	6 hr.	4.099	110.64	426.7	3.845	RT Discharge
15	10 hr.	4.159	3.865	112.13	RT	60	6 hr.	4.101	113.56	439.0	3.85	28F Discharge
16	10hr.	4.142	3.763	112.13	"	60	6 hr.	4.085	110.72	427.7	3.85	28F Discharge
17	10 hr.	4.136	3.754	112.13	"	60	6 hr.	4.082	109.97	424.8	3.85	RT Charge/Discharge
18	10 hr.	4.135	3.76	112.13	"	60	6 hr.	4.085	109.49	423.1	3.85	RT Charge/Discharge
19	10 hr.	4.141	3.818	112.13	28F	60	6 hr.	4.083	108.45	410.9	3.85	RT Charge/Discharge
20	10 hr.	4.147	3.866	112.13	RT	60	6 hr.	4.098	111.12	429.9	3.858	RT Charge/Discharge
21	10 hr.	4.137	3.828	112.13	28F	60	6 hr.	4.084	104.65	403.8	3.853	28F Discharge
22	10 hr.	4.177	3.876	112.13	28F	70	6 hr.	4.118	109.21	422.2	3.855	RT
23	10 hr.	4.159	3.878	112.13	RT	70	6 hr.	4.111	110.93	429.3	3.854	28 F Charge/Discharge
24	10 hr.	4.137	3.773	112.13	"	70	6 hr.	4.086	105	405.4	3.854	28F Charge/Discharge
25	10 hr.	4.148	3.788	112.13	"	70	6 hr.	4.098	104.855	404.5	3.849	28F Charge/Discharge
26	10 hr.	4.171	3.798	112.13	"	70	6 hr.	4.116	105.69	408.3	3.85	28F Charge/Discharge
27	10 hr.	4.178	3.798	112.13	"	70	6 hr.	4.123	103.97	401.73	3.85	28F Charge/Discharge
28	10 hr.	4.184	3.804	111.86	"	70	6 hr.	4.13	101.65	392.76	3.85	28F Charge/Discharge
29	10 hr.	4.184	3.802	109.91	"	70	6 hr.	4.128	98.55	372.72	3.846	28F Charge/Discharge
30	10 hr.	4.184	3.802	104.9	"	70	6 hr.	4.125	87.139	335.28	3.837	28F Charge/Discharge
31	10 hr.	4.184	3.819	97.03	"	70	6 hr.	4.123	83.07	319.30	3.825	28F Charge/Discharge
32	10 hr.	4.184	3.828	89.668	"	70	6 hr.	4.118	75.93	291.16	3.81	28F Charge/Discharge End of Test 10/16/97
33												
34												
35												
36												
37												
38												
39												
40												
41												
42												
43												
44												
45												
46												
47												
48												
49												
50												

% RETURN A: PERCENTAGE OF RATED CAPACITY.
% RETURN B: PERCENTAGE EFFICIENCY OF PREVIOUS CHARGE.

APPENDIX B

Smart Battery Controller Reference Manual

Alliant Technical Reference Manual

Theory Of Operation

Charging and Discharging

The primary function of the SBI board is to charge and discharge the cell to which it is attached. The SBI board has three charge states. They are trickle charge, constant current charge, and constant voltage charge. The ALLIANT Smart Battery Interface Program passes the charge parameters to each SBI board. The ALLIANT Smart Battery Interface Program then initiates a charge. The SBI board controls the charge. The charge cycle starts as a trickle charge. When the voltage is above a minimum set value and the temperature is above a minimum set value, the SBI board switches to constant current charge. When the voltage reaches the target voltage, the SBI board switches to the constant voltage charge. Once the SBI board is in the constant voltage charge, it remains there indefinitely. The SBI board meters the charge current to calculate capacity. The SBI board stores the capacity, but it is up to the ALLIANT Smart Battery Interface Program to keep this value up to date. The SBI board has four LEDs that are used to indicate the status.

The ALLIANT Smart Battery Interface Program integrates the cells to act as a battery system. The responsibility of the ALLIANT Smart Battery Interface Program include initiating the charge cycle, responding to the conditions of the charge cycle, and logging data from the charge cycle.

Microcontroller to PC Interface

The ALLIANT Smart Battery Interface Program runs on the host PC. The host PC communicates to the SBI boards through I2C and RS232 multiplexed communications. The I2C interface is used to update the host PC on voltage, current, and temperature of all of the SBI boards. The I2C interface cable plugs into the host PC parallel port. It has a PC power supply connector to power its active electronics. This must be plugged into the power plugs inside the host PC. The other end plugs into the I2C four-pin header on one of the SBI boards. The I2C signals are then daisy-chained to the other five SBI boards. The RS232 signals require a RS232 multiplexer box. This box is connected to each SBI board through a star configuration. The RS232 multiplexer box is then connected to host PC using a RS232 cable with DB9S connectors. During charge and discharge cycles, the Smart Battery Interface Program is constantly requesting current, voltage, and temperature from each SBI board. These values are typically sent across the I2C interface, but can be configured to be sent across the RS232 interface. All other communications between the host PC and the SBI boards is done through the RS232 interface.

Hardware

Processor Description

The microcontroller used for the SBI board is an 8-bit derivative of the 80C51-microcontroller family that either contains internal flash memory (ATMEL AT89C55), or internal EPROM (Philips P87C58EBLKA).

The Philips P87C58EBLKA is a self-contained microcontroller that contains 256 bytes of RAM and 32kbytes of EPROM. The microcontroller has a window in the top of it that allows it to be erased and reprogrammed. It has three built in timers, two hardware interruptible I/O pins, and a built in RS232 shift register.

The ATMEL AT89C55 is also a self-contained microcontroller that contains 256 bytes of RAM and 20kbytes of Flash RAM. Other than the 20kbytes of flash RAM instead of 32Kbytes of EPROM, the AT89C55 functions identically to the Philips P87C58EBLKA.

Microwire Devices

The microwire devices are the devices that communicate with the processor through a serial signal on the SBI board. There are three microwire devices. They are the DAC (MAX 539), the ADC (MAX148), and the EEPROM (93AA66).

The Maxim MAX539 Digital to Analog Converter is what the processor uses to control the charge voltage. The MAX539 is a 12 bit DAC that outputs twice the reference voltage and has a resolution of 2Ref / 4096 per step. The reference voltage is set to 2.5V.

The Maxim MAX148 Analog to Digital Converter is used by the processor to sense the voltage, current and temperature of the cell. The MAX148 is a 10 bit ADC that has a resolution of Ref / 1024. The reference voltage is set to 4.1V.

The Microchip 93AA66 is what the processor uses to store semi-permanent information. It can store 512 bytes. It is used to store information such as make, model, chemical, serial number and capacity of the cell. It also stores the calibration data for the SBI board.

Analog Devices

The Linear Tech LT1339 is a DC to DC converter chip that controls two IRL3803 MOSFETs to provide charge current. It uses Pulse Width Modulation on the gate of the MOSFETs to alternately turn them on and off.

The International Rectifier IRL3803 Power MOSFETs are used for several things on the board. First, they are used by the LT1339 to control the charge current using pulse width modulation. Second, they are used to connect the charger circuit to the cells. Third, they are used to connect the discharge load to the cell.

Calibration

The SBI boards each have calibration values for three volts, four volts, zero amperes, and twelve amperes. These calibration values are stored in the EEPROM. The SBI boards are calibrated at the factory, but a review of the calibration process follows. The tools and equipment required to recalibrate are:

- A twelve-volt six-ampere DC power supply.
- A precision variable DC power supply that is adjustable between three and four volts.
- A sixty-watt resistor rated between 249 milliohms and 333 milliohms.
- A calibrated voltmeter.
- A calibrated current meter that will measure twelve amperes.

Command line communication with the SBI board is necessary to calibrate. The SBI board command line commands use the address as part of the command. These procedures use address 16 in the examples. The SBI board must be disconnected from the cell to calibrate. The twelve-volt power supply must be connected to the SBI board charger connectors to calibrate.

Three volt calibration

To calibrate to 3 volts, follow the procedure listed below:

1. Connect the variable power supply to the cell post terminals on the SBI board. Make sure the voltage is already set to between 0 volts and 4.5 volts to avoid over voltage on the circuitry.
2. Using a calibrated voltmeter, adjust the voltage to 3 volts.
3. Read the voltage value returned by the ADC by doing **16 A V<cr>**. The SBI board will return a 3-digit hexadecimal number. This number is the 3-volt calibration number.
4. Do the command **16 X v XXX<cr>** where XXX is the 3-volt calibration number. This writes the calibration number to the board.

Four volt calibration

To calibrate to 4 volts, follow the procedure listed below:

1. Connect the variable power supply to the cell post terminals on the SBI board. Make sure the voltage is already set to between 0 volts and 4.5 volts to avoid over voltage on the circuitry.
2. Using a calibrated voltmeter, adjust the voltage to 4 volts.
3. Read the voltage value returned by the ADC by doing **16 A V<cr>**. The SBI board will return a 3-digit hexadecimal number. This number is the 4-volt calibration number.
4. Do the command **16 X V XXX<cr>** where XXX is the 4-volt calibration number. This writes the calibration number to the board.

Zero Ampere Calibration

To calibrate to 0 amperes, follow the procedure listed below:

1. Connect the variable power supply to the cell post terminals on the SBI board. Make sure the voltage is already set to between 0 volts and 4.5 volts to avoid over voltage on the circuitry.
2. Using a calibrated voltmeter, adjust the voltage to 4 volts.
3. Read the current value returned by the ADC by doing **16 A I<cr>**. The SBI board will return a 3-digit hexadecimal number. This number is the 0-ampere calibration number.
4. Do the command **16 X i XXX<cr>** where XXX is the 0-ampere calibration number. This writes the calibration number to the board.

Twelve Ampere Calibration

To calibrate to 12 amperes, follow the procedure listed below:

1. Connect the sixty-watt resistor in series with the calibrated current meter to the cell post terminals on the SBI board.

2. Slowly adjust the charge current up to 12 amperes using the command **16 E XXX<cr>** where **XXX** is a 3-digit hexadecimal number. Use the series 100, 180, 200, 280, ... until about twelve amperes is reached. Then adjust until exactly twelve amperes is reached.
3. Read the current value returned by the ADC by doing **16 A I<cr>**. The SBI board will return a 3-digit hexadecimal number. This number is the 0-ampere calibration number.
4. Do the command **16 E<cr>** to stop the SBI board from charging.
5. Do the command **16 X I XXX<cr>** where XXX is the 12-ampere calibration number. This writes the calibration number to the board.

Do these procedures for each board.

Firmware

The firmware for the microcontroller handles low-level functions for the host. These functions are listed below:

- Charge control
- Discharge control
- Report errors
- Report capacity
- Report Current
- Report Voltage
- Report Temperature

Charge Control

The SBI board checks the set point data when a charge is invoked. If the set point data is valid, then a charge is started. The SBI board has five states that it goes through when it charges. They are: INITIAL RAMP, TRICKLE CHARGE, RAMP UP, CONSTANT CURRENT, and CONSTANT VOLTAGE.

During the INITIAL RAMP charge state, the SBI board finds the point where the battery starts to draw current. This is necessary to get to the voltage of the battery to insure a linear response. This is in preparation for charging. The time that the SBI board is in this state is less than ten seconds.

During the TRICKLE CHARGE charge state, the SBI board charges at a low current until the voltage is above the minimum voltage set point and the temperature is above the minimum temperature set point.

During the RAMP UP charge state, the SBI board increases charge current until either the voltage reaches the target voltage set point or the current reaches target current set point. This process takes two to three minutes.

During the CONSTANT CURRENT charge state, the SBI board holds the current at the target current until the target voltage is reached.

During the CONSTANT VOLTAGE charge state, the SBI board holds the voltage at the target voltage. Once the charge circuit is in this state, it will maintain the target voltage until the charge is stopped.

Discharge Control

The SBI board checks the set point data when a discharge is invoked. If the set point is valid, then the SBI board turns on the positive and negative posts of the cell. The SBI board will keep the cell in discharge unless the discharge current is too high or the voltage drops below the minimum voltage.

Error Reporting

The SBI board can report on errors when they occur. The SBI board sends these error codes back to the host, but it also uses the LEDs on the board to indicate an error condition. The first LED flashes during normal operation, but is steady during an alarm condition. Any time the SBI board encounters an error during charge or discharge, it immediately goes to IDLE and reports the error. The errors and there corresponding error number are listed below:

1. Over Temperature during charge.
2. Over Current during charge.
3. Over Voltage during charge.
4. Bad Set Point Data.
5. Over Current during discharge.
6. Under Voltage during discharge.

The over temperature during charge alarm indicates that the cell has reached a dangerous temperature and must be shut down. The first LED is steady, the second and third LEDs are off, and the fourth LED is flashing when this error occurs.

The over current during charge alarm indicates that the charge current is greater than the maximum charge

current. The first LED is steady, the second and fourth LEDs are off, and the third LED is flashing when this error occurs.

The over voltage during charge alarm indicates that the cell voltage is greater than the maximum voltage. The first LED is steady, the second LED is off, and the third and fourth LEDs are flashing when this error occurs.

The bad set point data alarm indicates that the cell is already outside one of the charge or discharge parameters. The first LED is steady, the second LED is flashing, and the third and fourth LEDs are off when this error occurs.

The over current during discharge alarm indicates that the discharge current is greater than the maximum discharge current set point. The first LED is steady, the third LED is off, and the second and fourth LEDs are flashing when this error occurs.

The under voltage during discharge alarm indicates that the cell voltage is below the minimum voltage set point. The first LED is steady, the second and third LEDs are flashing, and the fourth LED is off when this error occurs.

Report Battery State

The SBI board reports the state of the cell to the ALLIANT Smart Battery Interface Program. The SBI board reports error codes, temperature, current, voltage, and capacity differentials. This information is used by the ALLIANT Smart Battery Interface Program to profile the performance of the cell.

RS232 Commands

This is a summary of all of the RS232 commands supported by each SBI board. These commands are intended to be used by the host computer, but they can be used to directly communicate with each board. Because these commands were intended to be used with the host computer, there are no safeguards to protect the user from issuing a potentially damaging or volatile command. Use caution with these commands. The SBI boards communicate at 9600 baud, 8 data bits, and no parity. Hexadecimal digits greater than 9 are represented by the letters A through F. These letters must be capitalized.

Formats:

aa X Z — Where **aa** is specific cell Address, **X** is command letter, **Z** data for command. All commands are terminated with a carriage return. The SMB will respond with an **ACK** on all correctly formatted commands followed by any requested data. The SMB will respond with a NAK on any incorrectly formatted commands.

The format for the **ACK** is:

aa A<cr> — where **aa** = address, **A** = the letter A, and **<cr>** = carriage return.

The format for the **NAK** is:

aa N<cr> — where **aa** = address, **N** = the letter N, and **<cr>** = carriage return.

Commands:

aa A X<cr>

Read ADC. This command reads the twelve-bit value from the Analog to Digital Converter. The ADC is used to read cell voltage, cell current, and temperature.
Command Format: **X**
- **I** = averaged current
- **R** = actual current.
- **T** = temperature
- **V** = voltage

Response: **ACK XXX<cr>**
Response Format:
- **XXX** = 3 bytes ASCII hex ADC value.

aa C S XXXYY<cr>

Set total cell capacity. This command stores the capacity in amp hours of the cell. The number is stored as a whole number. It has to be divided by 100 to read the actual value (i.e. 10700 = 107.00 amp hours).
Command Format:
- **XXX** = Amp hours in whole numbers.
- **YY** = Amp hours as fractional remainder.

Response: **ACK**

aa C G<cr>

Get total cell capacity.
Response: **ACK XXXYY<cr>**
Response Format:
- **XXX** = Amp hours in whole numbers
- **YY** = Amp hours as fractional remainder

aa C U<cr>

Get capacity used. This command gets the measured amp hours added / removed from cell since last charge / discharge command.
Response: **ACK HHMMmmmsss<cr>**
Response Format:
- **HH** = Amp Hours
- **MM** = Amp Minutes
- **mmm** = Milli Amp Minutes
- **sss** = Milli Amp Seconds

aa E<cr> Stop blind charge. This is a debug command that allows a blind charge to be stopped.
Response: **ACK**

aa E XXX<cr> Start blind charge. This is a debug command that allows a blind charge to be started. **XXX** = Hexadecimal number to write to the DAC. 000 - FFF
Response: **ACK**

aa F<cr> Initialize new cell. This command zeroes charge cycle count, discharge cycle count, and total cell capacity.
Response: **ACK**

aa G X<cr> Go command. This command starts and stops the smart chargers charge and discharge cycles.
Command Format: **X**:
- **S** = Start Charge
- **E** = End Charge
- **s** = start Discharge
- **e** = end Discharge

Response: **ACK**

aa I XXX<cr> Absolute maximum charge current.
Command Format:
- **XXX** = value to set in ASCII hex.

Response: **ACK XXX<cr>**
Response Format:
- **XXX** = confirmation that the value was set correctly.

aa K<cr> Returns alarms.
Response: **ACK XX <cr>** where **XX** = 2 bytes of ASCII Hex.

aa L X Y<cr> Look at RAM or EEPROM where **X** is:
- **R** = RAM
- **E** = EEPROM

and Y = **XXX** 3 bytes of ASCII HEX.
Range:
- Ram: 000 to 0FF.
- EEPROM: 000 to 1FF.

Response: **ACK XX<cr>** where **XX** = 2 bytes of ASCII Hex

aa M<cr> Request accumulator dump. ie: cycle counts, battery information.
Response: **ACK AAAAAAAAAA BBBBBBBBBB CCCCCCCCCC DDD EEE FFF GGG HHH III JJJ KKK LLL MMM NNN OOO PPP QQQ RRR SSS<cr>**
Format:
- **A** = Manufacturer (10)
- **B** = Model (10)
- **C** = Chemical (10)
- **D** = Charge cycles (3)
- **E** = Discharge cycles (3)
- **F** = Minimum temperature (3)
- **G** = Maximum temperature (3)
- **H** = Absolute minimum voltage (3)
- **I** = Minimum voltage before high charge (3)
- **J** = Target voltage (3)
- **K** = Maximum voltage (3)
- **L** = Trickle charge current (3)
- **M** = Target charge current (3)
- **N** = Maximum charge current (3)
- **O** = Maximum discharge current (3)

P = Calibration 3 volts (3)
Q = Calibration 4 volts (3)
R = Calibration 0 amperes (3)
S = Calibration 12 amperes (3)

aa N XXXXXXXX<cr> Set cell serial number. Eight alphanumeric characters.
Response: **ACK**

aa O<cr> Get cell serial number. Eight alphanumeric characters.
Response: **ACK XXXXXXXX<cr>**

aa Q<cr> Re-calibrate 0 amperes. This command automatically re-calibrates 0 amperes and must be issued when the cell is idle.
Response: **ACK**

aa R X<cr> Reset. This command resets the alarm or resets the cells microcontroller. It resets the microcontroller by going into an endless loop and waiting for the watchdog (MAX1232) to reset the controller.
Format: **X** is:
A = Alarm reset.
I = Initialize entire board.
Response: **ACK**

aa S p XXX<cr> Set set point. This command is used to set the various set points. All values in 3-digit ASCII hex for ADC comparison where **p** is:
t = Minimum temperature before high charge is allowed.
T = Maximum temperature before shutdown.
v = Minimum voltage before high charge is allowed.
V = Target charge voltage.
i = Trickle charge current.
I = Target charge current.
D = Maximum discharge current allowed.
Response: **ACK XXX<cr>** Format: **XXX** is confirmation that the value was set correctly.

aa v XXX<cr> Set absolute minimum voltage. This command sets the absolute minimum operational voltage.
Format: **XXX** is in ASCII hex.
Response: **ACK**

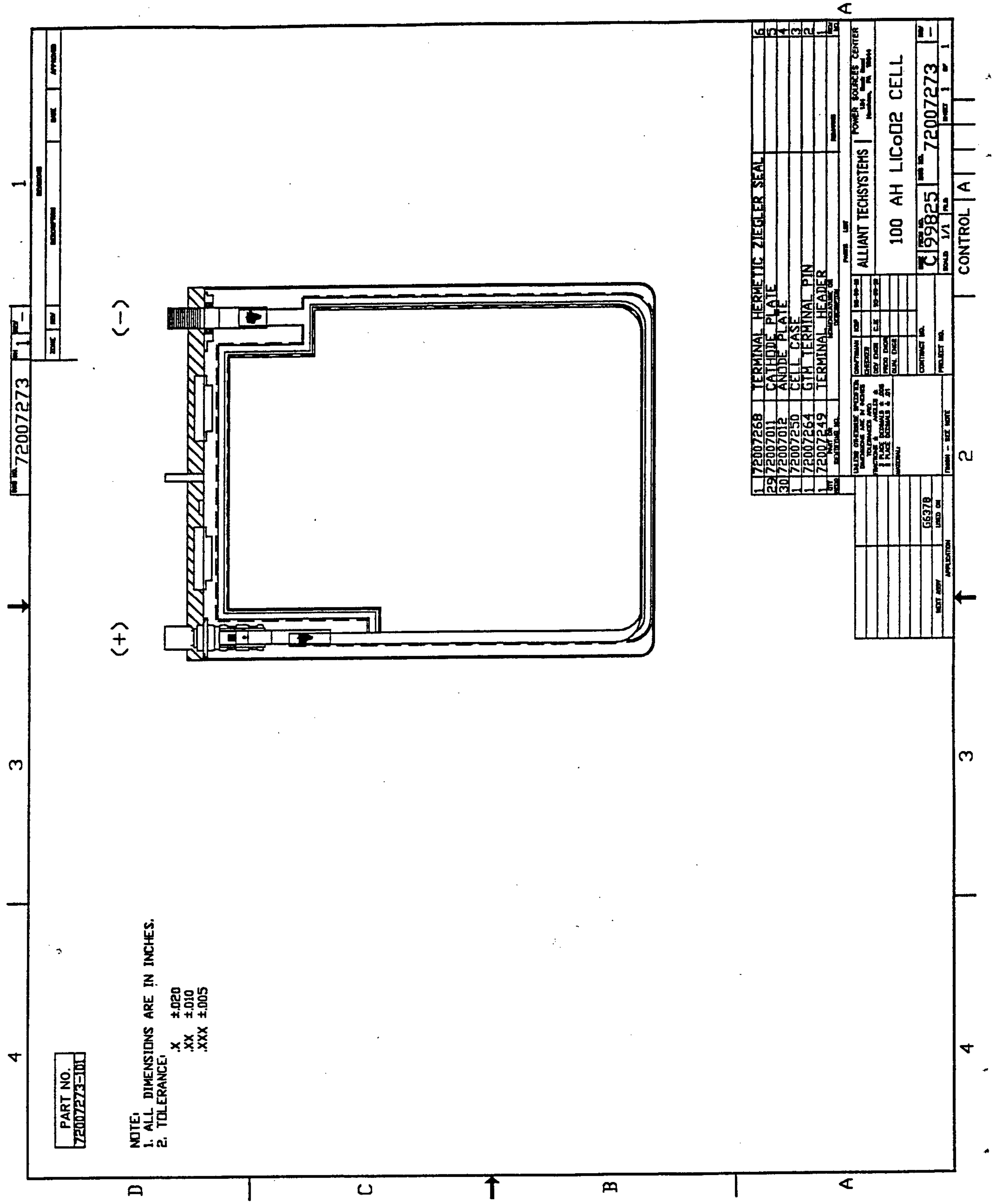
aa V XXX<cr> Absolute maximum voltage. Where **XXX** is in ASCII hex.
Response: **ACK**

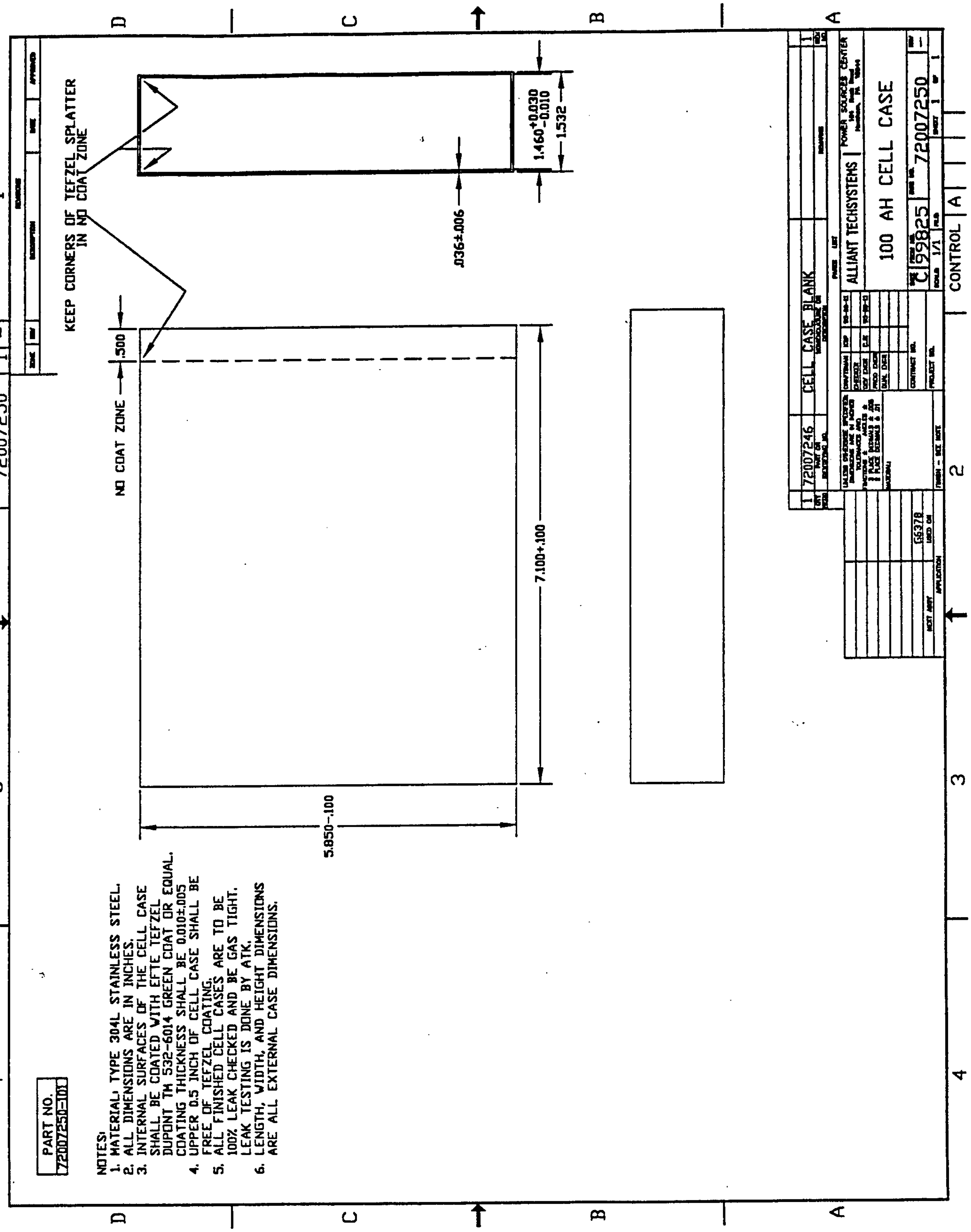
aa W X Y Z<cr> Write to RAM, EEPROM (calls EEPROM write, unlock should occur just long enough to write, then it should be locked) where:
X = Resource. (RAM or EEPROM)
Y = Address. (000 - 1FF)
Z = Data to be stored. (00 - FF)
Response: **ACK**

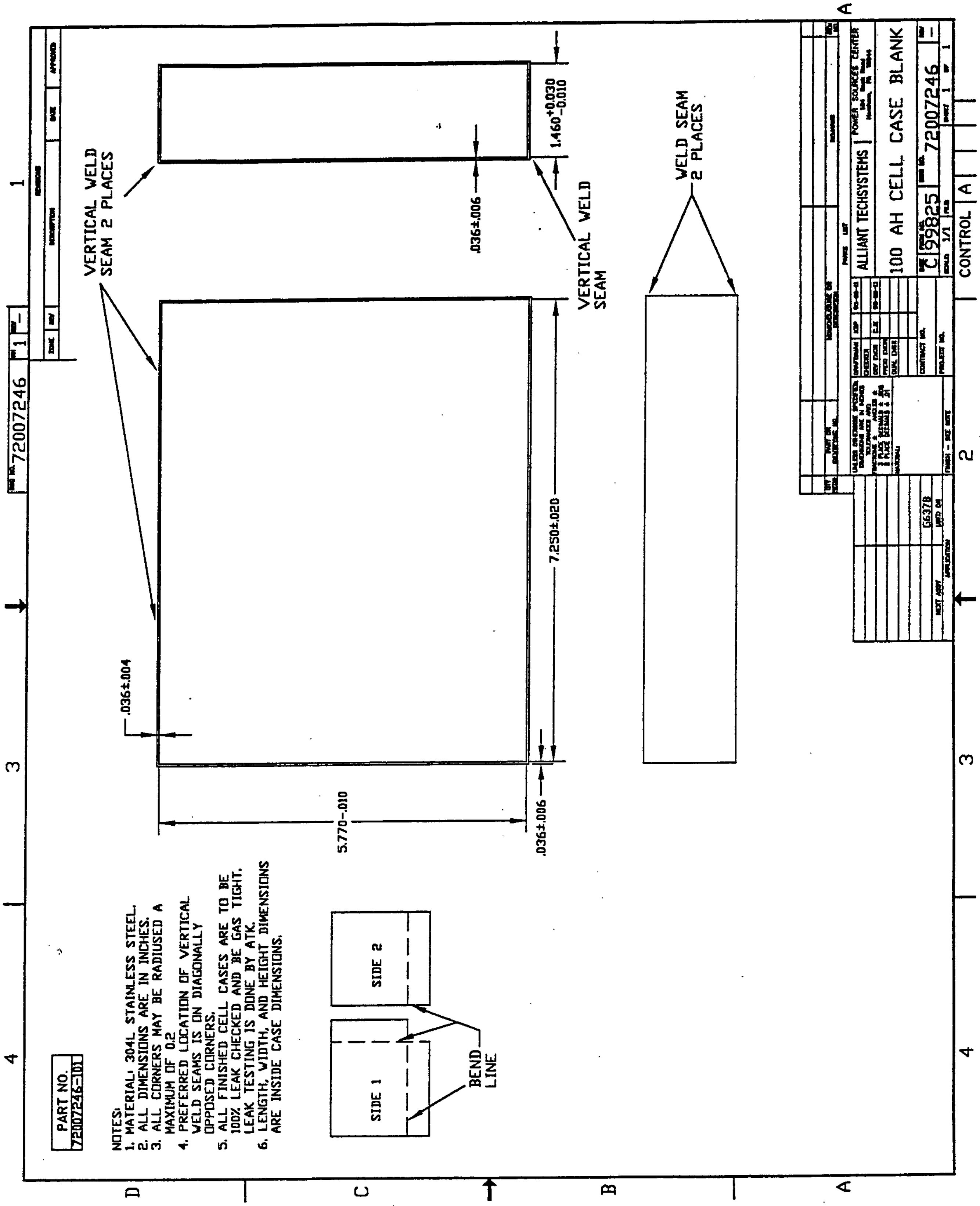
aa Z<cr> Set factory defaults. This command sets manufacturer, model, and chemical back to factory defaults.
Response: **ACK**

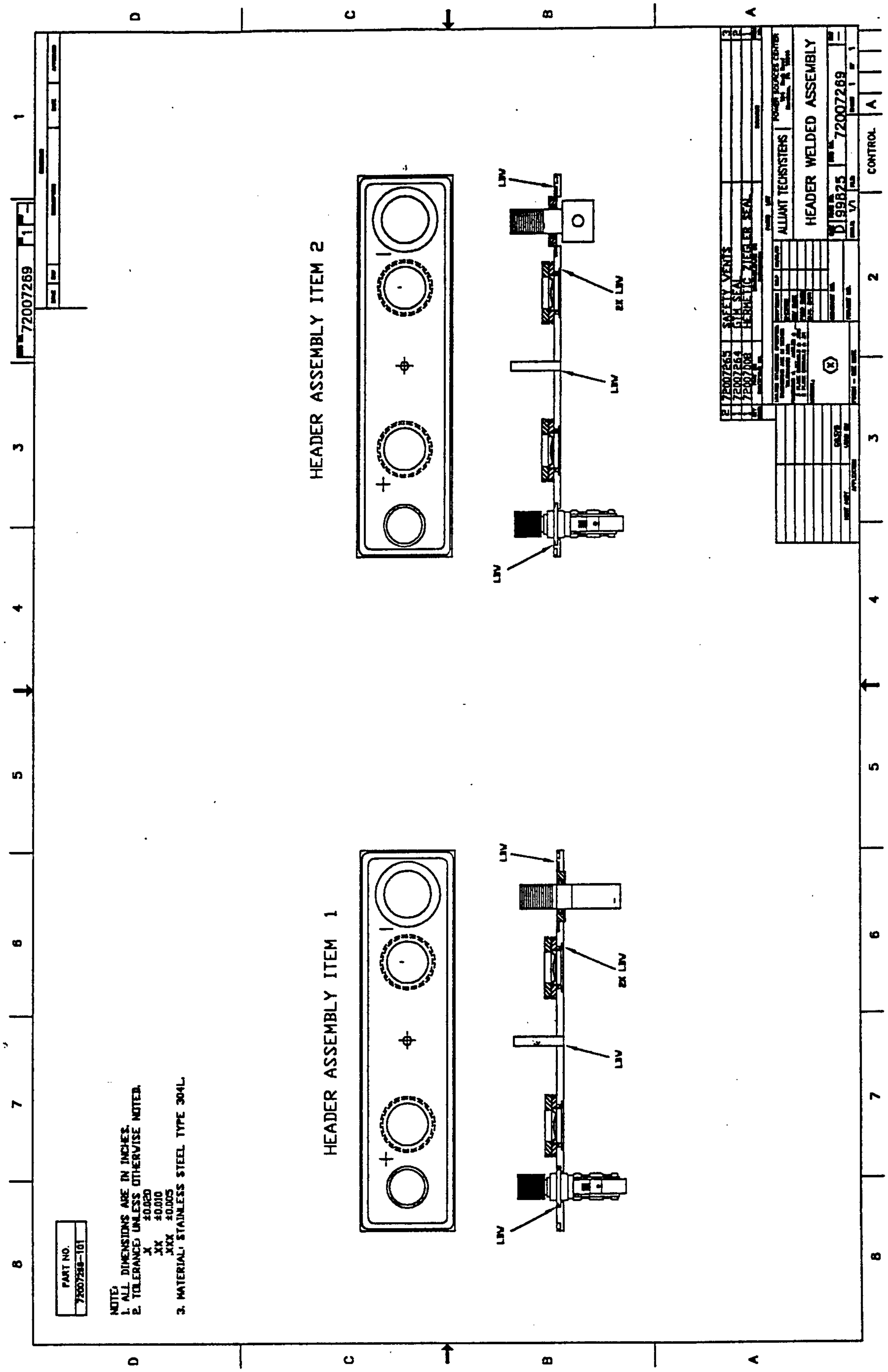
APPENDIX C

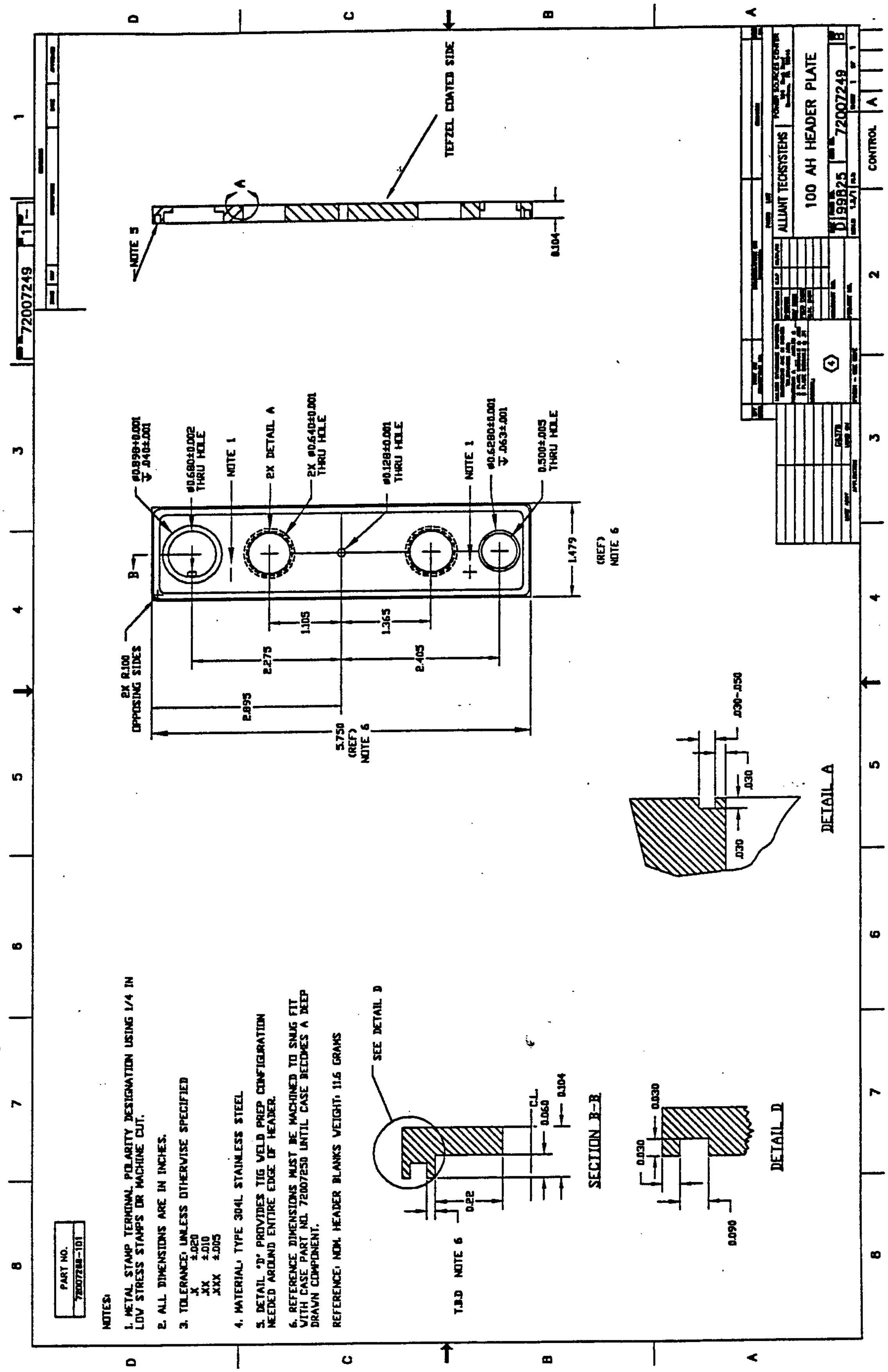
100 Ah $Li_{0.5}CoO_2$ DRAWING PACKAGE

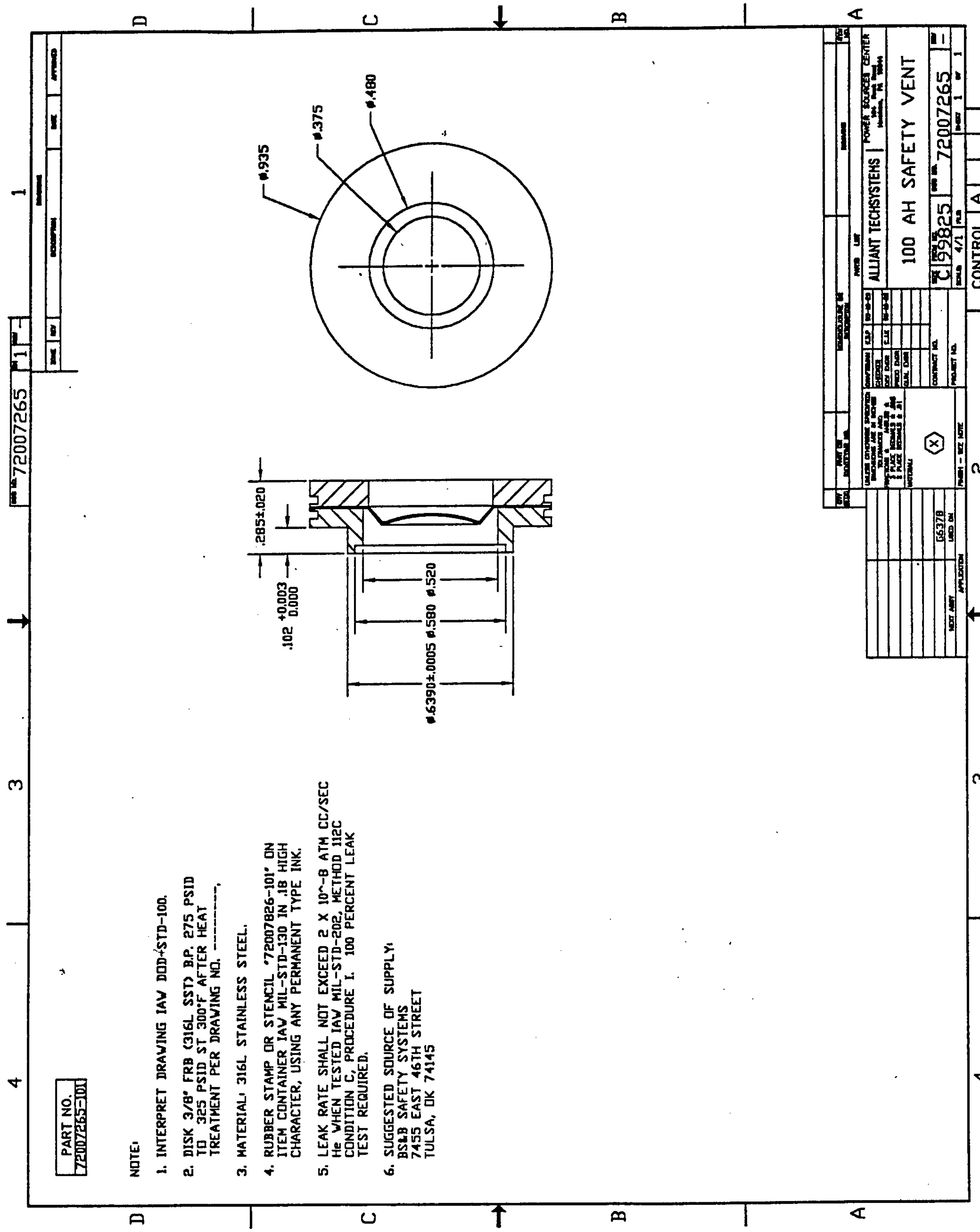

72007273
(+)
(-)
1 72007268 TERMINAL, HERMETIC ZIEGLER SEAL 6
29 72007011 CATHODE PLATE 5
30 72007012 ANODE PLATE 4
1 72007250 CELL CASE 3
1 72007264 GTM TERMINAL PIN 2
1 72007249 TERMINAL HEADER 1
ALLIANT TECHSYSTEMS
POWER SOURCES CENTER
100 AH LiCoO2 CELL
C 99825 72007273
SCALE 1/1 SHEET 1 OF 1
CONTROL A
G6378
PART NO. 72007273-01
NOTE:
1. ALL DIMENSIONS ARE IN INCHES.
2. TOLERANCE: .X ±.020 .XX ±.010 .XXX ±.005


72007250
KEEP CORNERS OF TEFZEL SPLATTER IN NO COAT ZONE
NO COAT ZONE
.500
7.100+.100
5.850-.100
1.460 +0.030 -0.010
1.532
.036±.006
PART NO.
72007250-101
NOTES:
1. MATERIAL: TYPE 304L STAINLESS STEEL.
2. ALL DIMENSIONS ARE IN INCHES.
3. INTERNAL SURFACES OF THE CELL CASE SHALL BE COATED WITH EFTE TEFZEL DUPONT TM 532-6014 GREEN COAT OR EQUAL. COATING THICKNESS SHALL BE 0.010±.005
4. UPPER 0.5 INCH OF CELL CASE SHALL BE FREE OF TEFZEL COATING.
5. ALL FINISHED CELL CASES ARE TO BE 100% LEAK CHECKED AND BE GAS TIGHT. LEAK TESTING IS DONE BY ATK.
6. LENGTH, WIDTH, AND HEIGHT DIMENSIONS ARE ALL EXTERNAL CASE DIMENSIONS.
1 72007246 CELL CASE BLANK
ALLIANT TECHSYSTEMS
POWER SOURCES CENTER
100 AH CELL CASE
C 99825 72007250
SCALE 1/1
SHEET 1 OF 1
G6378
CONTROL A


PART NO.
72007246-101
NOTES:
1. MATERIAL: 304L STAINLESS STEEL.
2. ALL DIMENSIONS ARE IN INCHES.
3. ALL CORNERS MAY BE RADIUSED A MAXIMUM OF 0.2
4. PREFERRED LOCATION OF VERTICAL WELD SEAMS IS ON DIAGONALLY OPPOSED CORNERS.
5. ALL FINISHED CELL CASES ARE TO BE 100% LEAK CHECKED AND BE GAS TIGHT. LEAK TESTING IS DONE BY ATK.
6. LENGTH, WIDTH, AND HEIGHT DIMENSIONS ARE INSIDE CASE DIMENSIONS.
SIDE 1
SIDE 2
BEND LINE
VERTICAL WELD SEAM 2 PLACES
VERTICAL WELD SEAM
WELD SEAM 2 PLACES
.036±.004
.036±.006
5.770-.010
7.250±.020
1.460+0.030 -0.010
72007246
ALLIANT TECHSYSTEMS
POWER SOURCES CENTER
100 AH CELL CASE BLANK
C 99825 72007246
SCALE 1/1
CONTROL A
G6378


HEADER ASSEMBLY ITEM 2
HEADER ASSEMBLY ITEM 1
2X
NOTE:
1. ALL DIMENSIONS ARE IN INCHES.
2. TOLERANCE: UNLESS OTHERWISE NOTED.
.X ±0.020
.XX ±0.010
.XXX ±0.005
3. MATERIAL: STAINLESS STEEL TYPE 304L.
PART NO.
72007265 SAFETY VENTS
72007264 GTM SEAL
72007008 HERMETIC ZIEGLER SEAL
ALLIANT TECHSYSTEMS
HEADER WELDED ASSEMBLY
72007269
CONTROL


PART NO. 72007248-101
NOTES:
1. METAL STAMP TERMINAL POLARITY DESIGNATION USING 1/4 IN LOW STRESS STAMPS OR MACHINE CUT.
2. ALL DIMENSIONS ARE IN INCHES.
3. TOLERANCE: UNLESS OTHERWISE SPECIFIED .X ±.020 .XX ±.010 .XXX ±.005
4. MATERIAL: TYPE 304L STAINLESS STEEL
5. DETAIL 'D' PROVIDES TIG WELD PREP CONFIGURATION NEEDED AROUND ENTIRE EDGE OF HEADER.
6. REFERENCE DIMENSIONS MUST BE MACHINED TO SNUG FIT WITH CASE PART NO. 72007250 UNTIL CASE BECOMES A DEEP DRAWN COMPONENT.
REFERENCE: NOM. HEADER BLANKS WEIGHT: 11.6 GRAMS
SECTION B-B
DETAIL D
DETAIL A
SEE DETAIL D
TEFZEL COATED SIDE
NOTE 5
NOTE 1
2X DETAIL A
2X R.100 OPPOSING SIDES
0.128±0.001 THRU HOLE
0.500±.005 THRU HOLE
2X ø0.640±0.001 THRU HOLE
ø0.680±0.002 THRU HOLE
5.750 (REF) NOTE 6
1.479 (REF) NOTE 6
ALLIANT TECHSYSTEMS
100 AH HEADER PLATE
D 99B25
72007249
CONTROL A

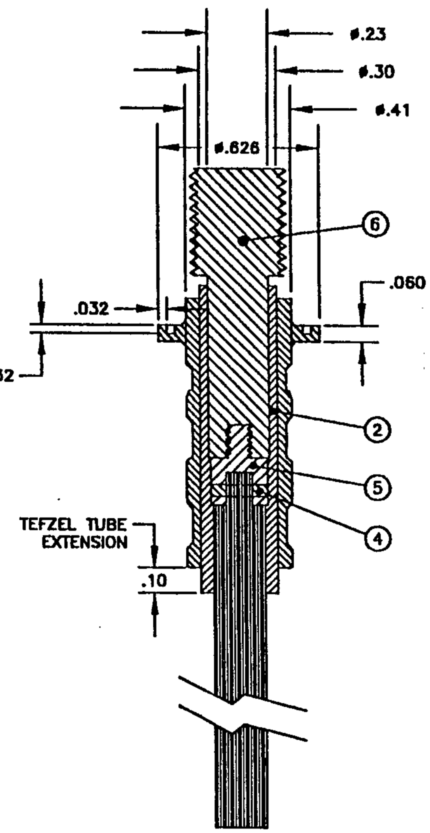

72007265
PART NO.
72007265-101
NOTE:
1. INTERPRET DRAWING IAW DOD-STD-100.
2. DISK 3/8" FRB (316L SST) B.P. 275 PSID TO 325 PSID ST 300°F AFTER HEAT TREATMENT PER DRAWING NO. ______.
3. MATERIAL: 316L STAINLESS STEEL.
4. RUBBER STAMP OR STENCIL "72007826-101" ON ITEM CONTAINER IAW MIL-STD-130 IN .18 HIGH CHARACTER, USING ANY PERMANENT TYPE INK.
5. LEAK RATE SHALL NOT EXCEED 2 X 10^-8 ATM CC/SEC He WHEN TESTED IAW MIL-STD-202, METHOD 112C CONDITION C, PROCEDURE I. 100 PERCENT LEAK TEST REQUIRED.
6. SUGGESTED SOURCE OF SUPPLY:
BS&B SAFETY SYSTEMS
7455 EAST 46TH STREET
TULSA, OK 74145
ø.935
ø.375
ø.480
.285±.020
.102 +0.003 0.000
ø.520
ø.580
ø.6390±.0005
ALLIANT TECHSYSTEMS
POWER SOURCES CENTER
100 AH SAFETY VENT
C 99825
72007265
SCALE 4/1
SHEET 1 OF 1
CONTROL A
G6378

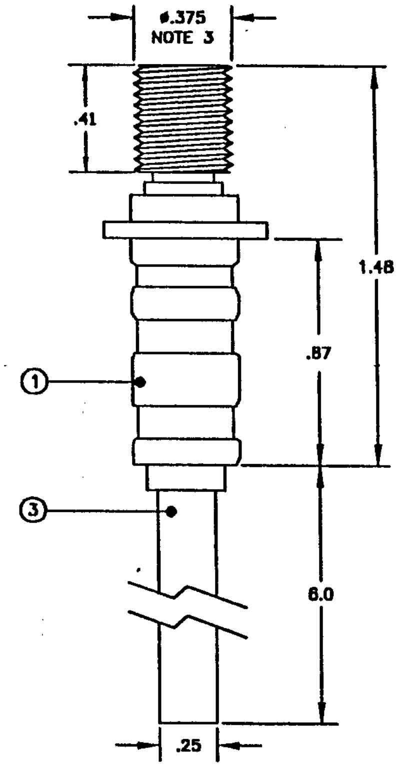
ZONE	REV	DESCRIPTION	DATE	APPROVED
	A	GENERAL REVISIONS	97-01-21	LDU
	B	GENERAL REVISIONS	97-11-12	LDU

DWG NO. 72007268 SH 1 REV B

PART NO.
72007268-101

NOTE:
1. ALL DIMENSIONS ARE IN INCHES
   .X ±.050
   .XX ±.020
   .XXX ±.001
2. ALUMINUM CONDUCTOR SHALL BE DEAD SOFT ON THE TAB END AND 1100 GRADE.
3. THREAD SIZE IS .375-24UNF-3A
4. THE SEAL IS APPROVED FOR USE AT 50 AMPHERE CONSTANT CURRENT.
5. LEAK RATE LESS THAN 2 x 10^{-8} CC/SEC OF He.
6. SOURCE OF SUPPLY:
   3E LABORATORIES, INC
   840 MAIN ST.
   LANSDALE, PA
   OTHER SUPPLIERS MUST BE APPROVED BEFORE PURCHASE.





PARTS LIST

QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	REMARKS	ITEM NO.
1	6	THREADED TERMINAL	NICKEL 200	6
1	5	FORKED TAB HOLDER	ALUMINUM	5
1	4	PIN	ALUMINUM 1100/1200	4
32	3	CONDUCTOR 0.005 THK	ALUMINUM 1100/1200	3
1	2	SEAL TUBE	TEFZEL	2
1	1	OUTER CRIMP JACKET & FLANGE	316L STAINLESS STEEL	1

G6378

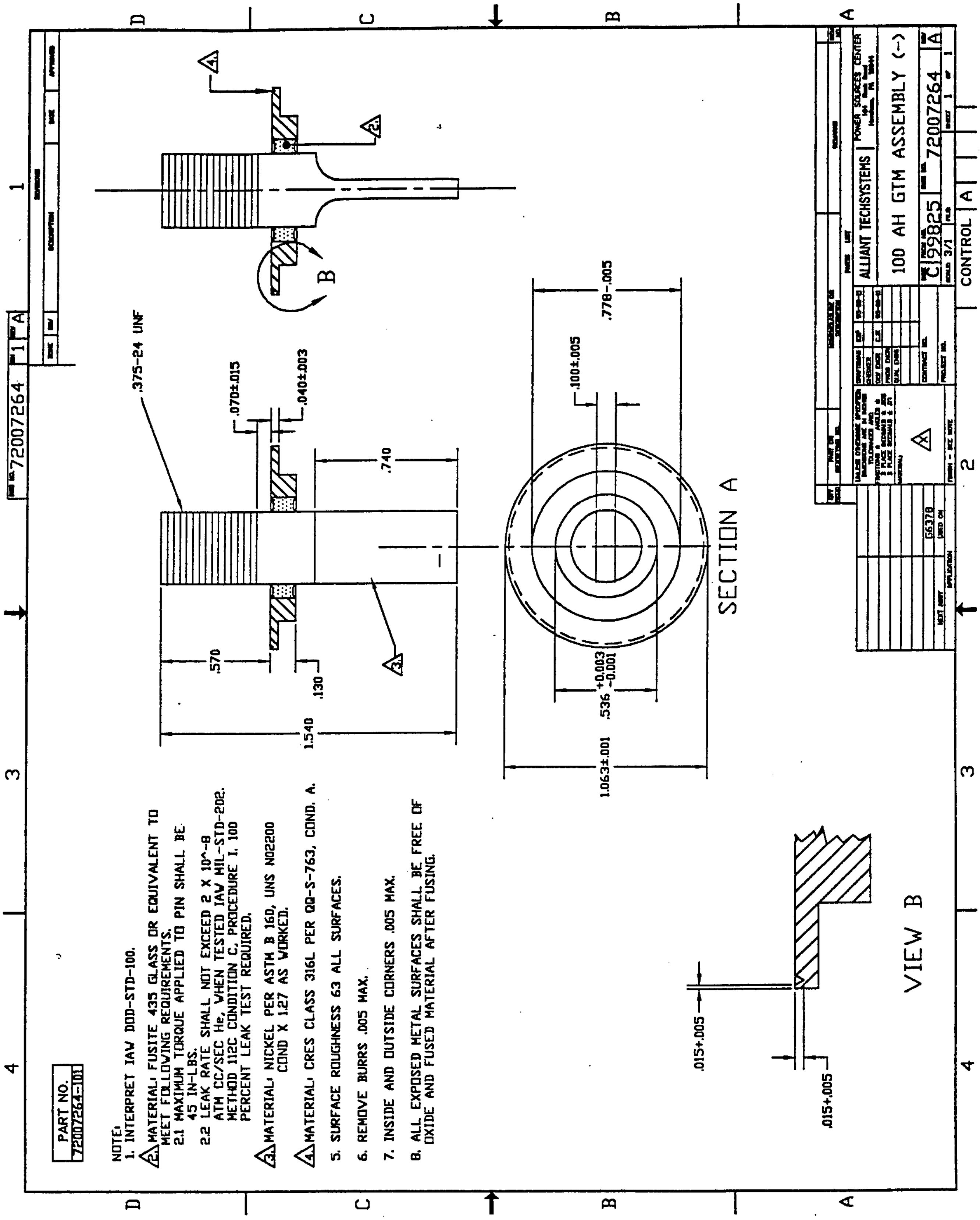
ALLIANT TECHSYSTEMS | POWER SOURCES CENTER

100 AH TERMINAL ZIEGLER HERMETIC SEALS

SIZE C | FSCM NO. 99825 | DWG NO. 72007268 | REV B

SCALE 3/1 | SHEET 1 OF 1

CONTROL A

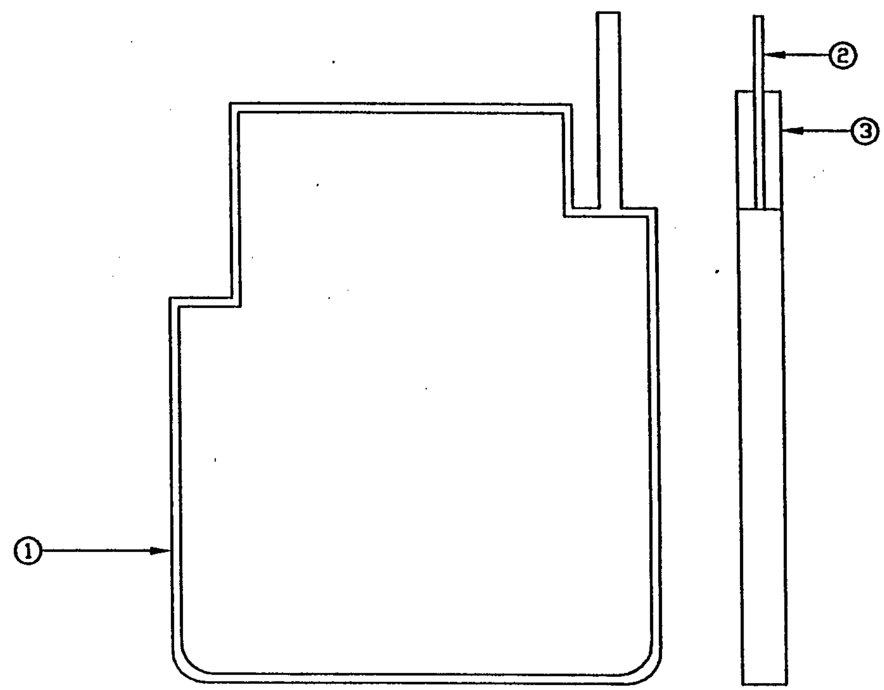


PART NO.
72007264-101
NOTE:
1. INTERPRET IAW DOD-STD-100.
2. MATERIAL: FUSITE 435 GLASS OR EQUIVALENT TO MEET FOLLOWING REQUIREMENTS.
2.1 MAXIMUM TORQUE APPLIED TO PIN SHALL BE 45 IN-LBS.
2.2 LEAK RATE SHALL NOT EXCEED 2 X 10^-8 ATM CC/SEC He, WHEN TESTED IAW MIL-STD-202, METHOD 112C CONDITION C, PROCEDURE I. 100 PERCENT LEAK TEST REQUIRED.
3. MATERIAL: NICKEL PER ASTM B 160, UNS N02200 COND X 1.27 AS WORKED.
4. MATERIAL: CRES CLASS 316L PER QQ-S-763, COND. A.
5. SURFACE ROUGHNESS 63 ALL SURFACES.
6. REMOVE BURRS .005 MAX.
7. INSIDE AND OUTSIDE CORNERS .005 MAX.
8. ALL EXPOSED METAL SURFACES SHALL BE FREE OF OXIDE AND FUSED MATERIAL AFTER FUSING.
.375-24 UNF
.070±.015
.040±.003
.740
.570
.130
1.540
.100±.005
.778-.005
.536 +0.003 -0.001
1.063±.001
SECTION A
VIEW B
.015±.005
.015±.005
72007264
ALLIANT TECHSYSTEMS
POWER SOURCES CENTER
100 AH GTM ASSEMBLY (-)
C 99825 72007264 A
SCALE 3/1
SHEET 1 OF 1
CONTROL A
66378

72007012 1 A

PART NO. 72007012-101

NOTES:
1. TAB SURFACES SHALL BE CLEAN OF LITHIUM METAL.
2. TWO ANODE OUT OF THE TWENTY FOUR ARE TO BE FABRICATED WITH LITHIUM FOIL ON ONE SIDE ONLY. EACH IS OPPOSITE HAND.
3. TOLERANCES:
   .X ±0.020
   .XX ±0.010
   .XXX ±0.005
4. ALL DIMENSIONS ARE IN INCHES.
5. CURRENT COLLECTOR PER 72007253.
6. LITHIUM FOIL AND NICKEL ETCH CURRENT COLLECTOR ARE LAMINATED TOGETHER THEN CUT TO SHAPE.
7. APPROXIMATE LITHIUM USAGE: ONE 1/4 CAN PER 100AH CELL. ROLL WIDTH 6", THICKNESS 0.006". VENDOR: FMC
8. SURFACE AREA PER SIDE=187.35 SQ. CM SURFACE AREA PER PLATE=374.70 SQ. CM



QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	REMARKS	FIND NO.
2	72007259	100AH ANODE PADS		3
1	72007253	ANODE CURRENT COLLECTOR		2
2	72007258	100AH GRAPHITE BORDER		1

PARTS LIST

NEXT ASSY	USED ON
72007262	G6378

APPLICATION

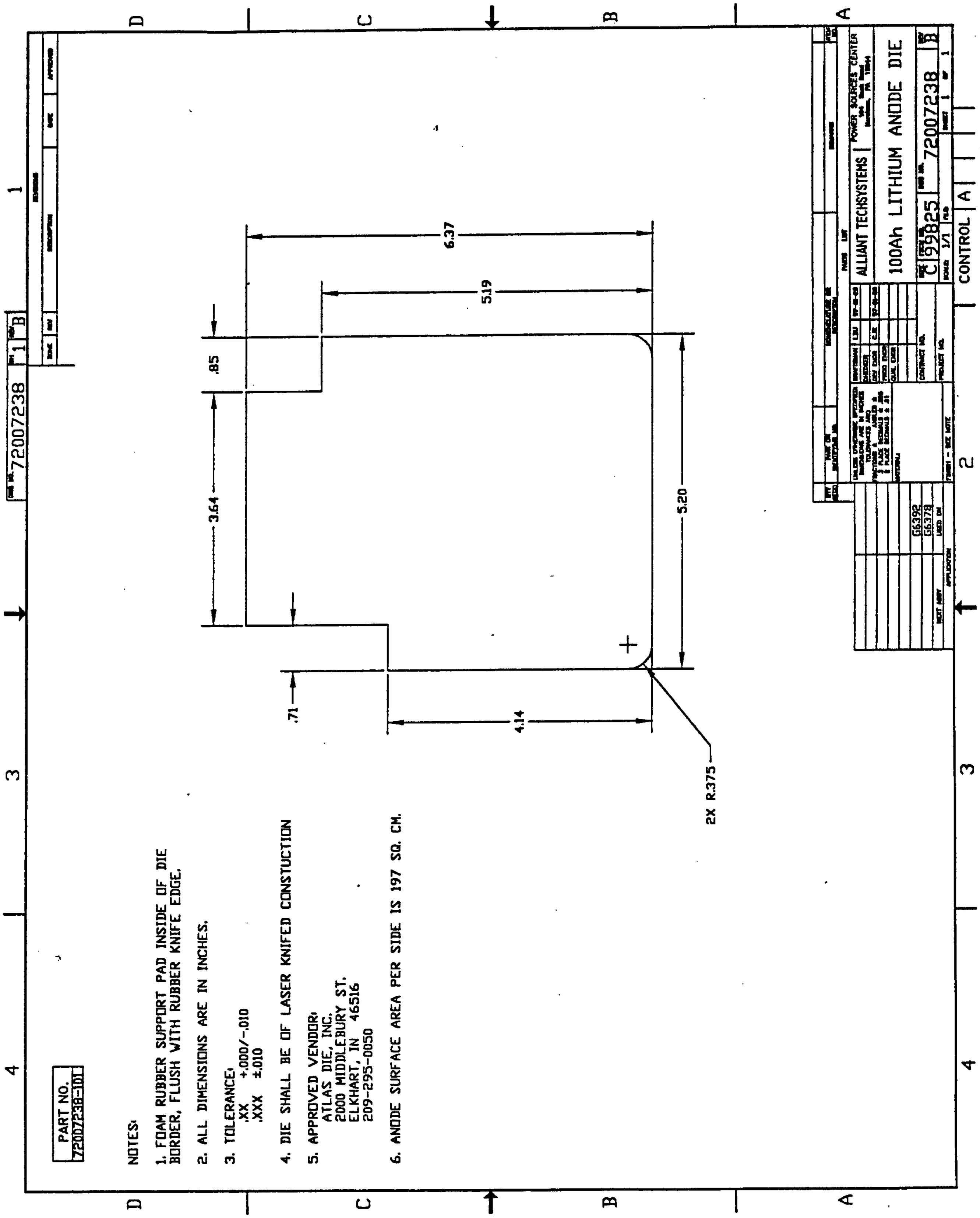
ALLIANT TECHSYSTEMS | POWER SOURCES CENTER

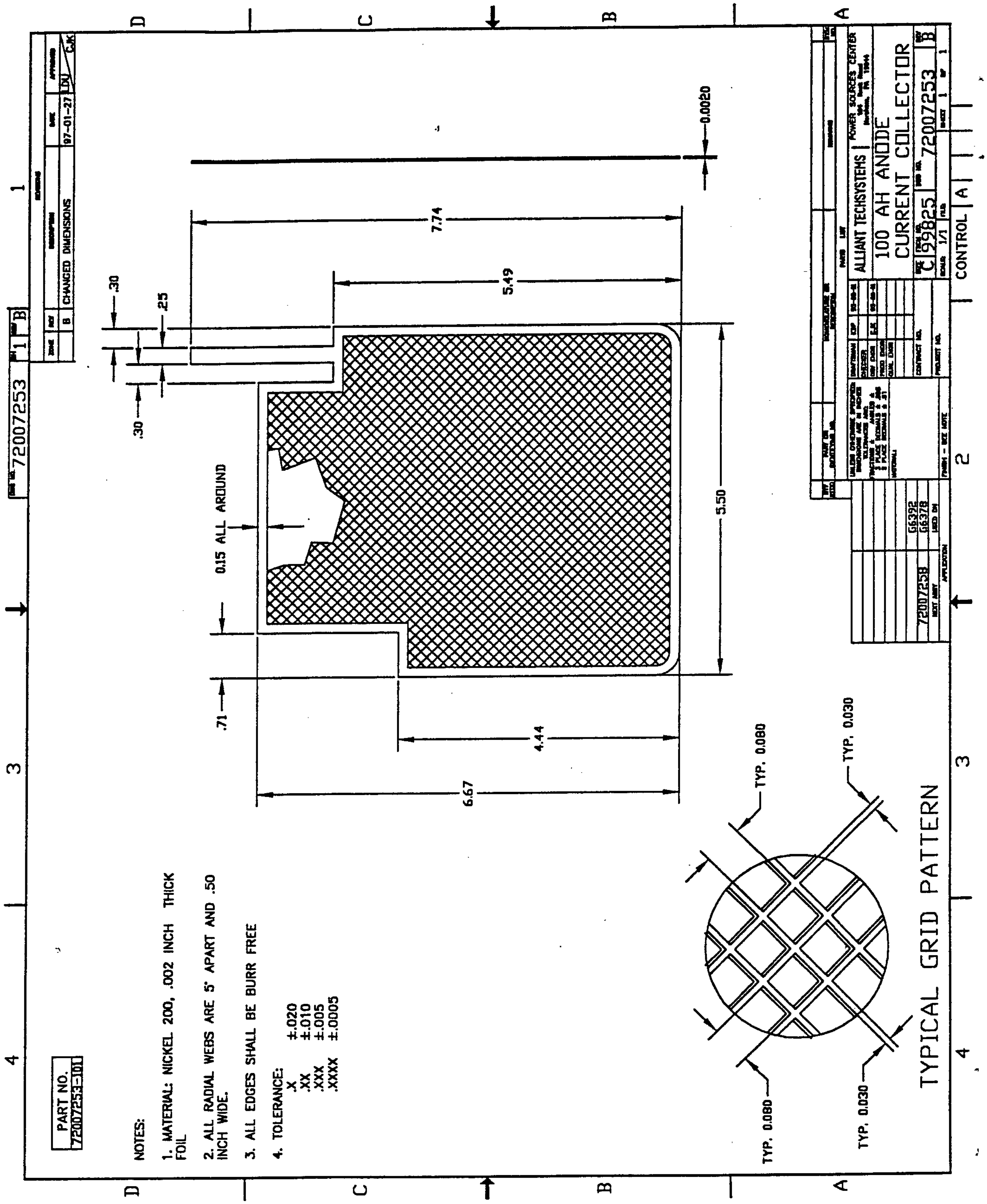
100 AH ANODE PLATE

SIZE C | FSCM NO. 99825 | DWG NO. 72007012 | REV A

SCALE 1/1 | SHEET 1 OF 1

CONTROL A

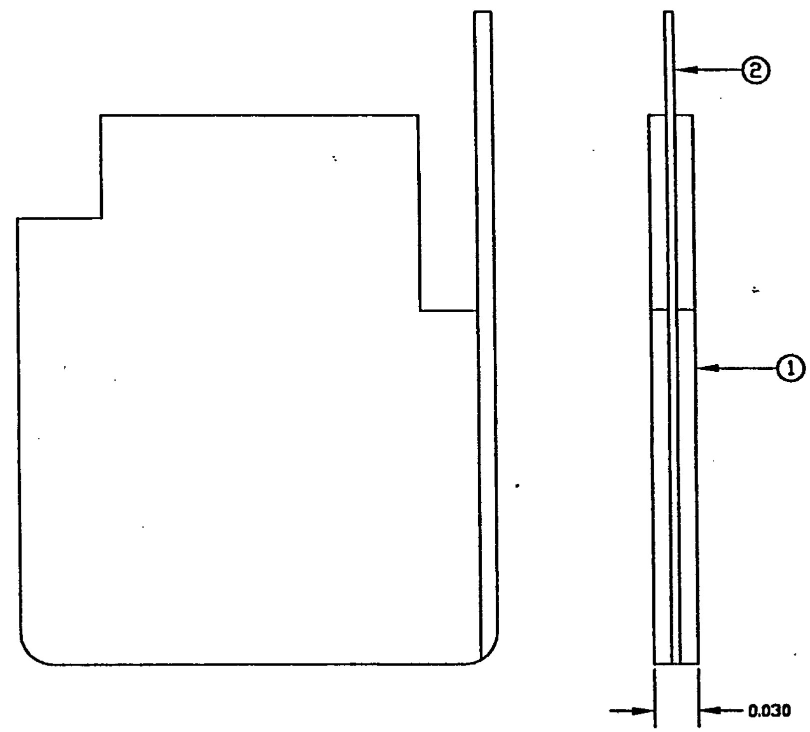

72007238
1
B
6.37
5.19
.85
3.64
5.20
.71
4.14
2X R.375
PART NO.
72007238-101
NOTES:
1. FOAM RUBBER SUPPORT PAD INSIDE OF DIE BORDER, FLUSH WITH RUBBER KNIFE EDGE.
2. ALL DIMENSIONS ARE IN INCHES.
3. TOLERANCE:
.XX +.000/-.010
.XXX ±.010
4. DIE SHALL BE OF LASER KNIFED CONSTUCTION
5. APPROVED VENDOR:
ATLAS DIE, INC.
2000 MIDDLEBURY ST.
ELKHART, IN 46516
209-295-0050
6. ANODE SURFACE AREA PER SIDE IS 197 SQ. CM.
ALLIANT TECHSYSTEMS
POWER SOURCES CENTER
100Ah LITHIUM ANODE DIE
C 59825 72007238 B
SCALE 1/1
SHEET 1 OF 1
CONTROL A
G6392
G6378


72007253
CHANGED DIMENSIONS
97-01-27
PART NO.
72007253-101
NOTES:
1. MATERIAL: NICKEL 200, .002 INCH THICK FOIL
2. ALL RADIAL WEBS ARE 5° APART AND .50 INCH WIDE.
3. ALL EDGES SHALL BE BURR FREE
4. TOLERANCE:
.X ±.020
.XX ±.010
.XXX ±.005
.XXXX ±.0005
0.15 ALL AROUND
7.74
5.49
5.50
4.44
6.67
.71
.30
.25
.30
0.0020
TYP. 0.080
TYP. 0.030
TYPICAL GRID PATTERN
ALLIANT TECHSYSTEMS
POWER SOURCES CENTER
100 AH ANODE CURRENT COLLECTOR
C 99825 72007253 B
SCALE 1/1
SHEET 1 OF 1
CONTROL A
72007258
G6392
G6378
NEXT ASSY
USED ON
APPLICATION

72007011 1 A

PART NO.
72007011-101

NOTE;
1. TAB SURFACES SHALL BE CLEAN OF CATHODE MATERIAL.
2. CATHODE SURFACES AREA PER SIDE IS 170 sq cm.
3. REF. CATHODE PRODUCTION PROCESS DETAIL 7200711-1.
4. TOLERANCE: .X ±0.020
   .XX ±0.010
   .XXX ±0.005
5. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE NOTED.
6. PER PROCESS PROCEDURE: T.B.D



QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	ITEM NO.
1	72007261	CATHODE SUBASSEMBLY	2
1	72007242	100 AH CATHODE GRID	1

PARTS LIST

NEXT ASSY	USED ON
72007263	G6378

APPLICATION

FINISH – SEE NOTE

ALLIANT TECHSYSTEMS | POWER SOURCES CENTER

100 AH CATHODE PLATE

SIZE C | FSCM NO. 99825 | DWG NO. 72007011 | REV A

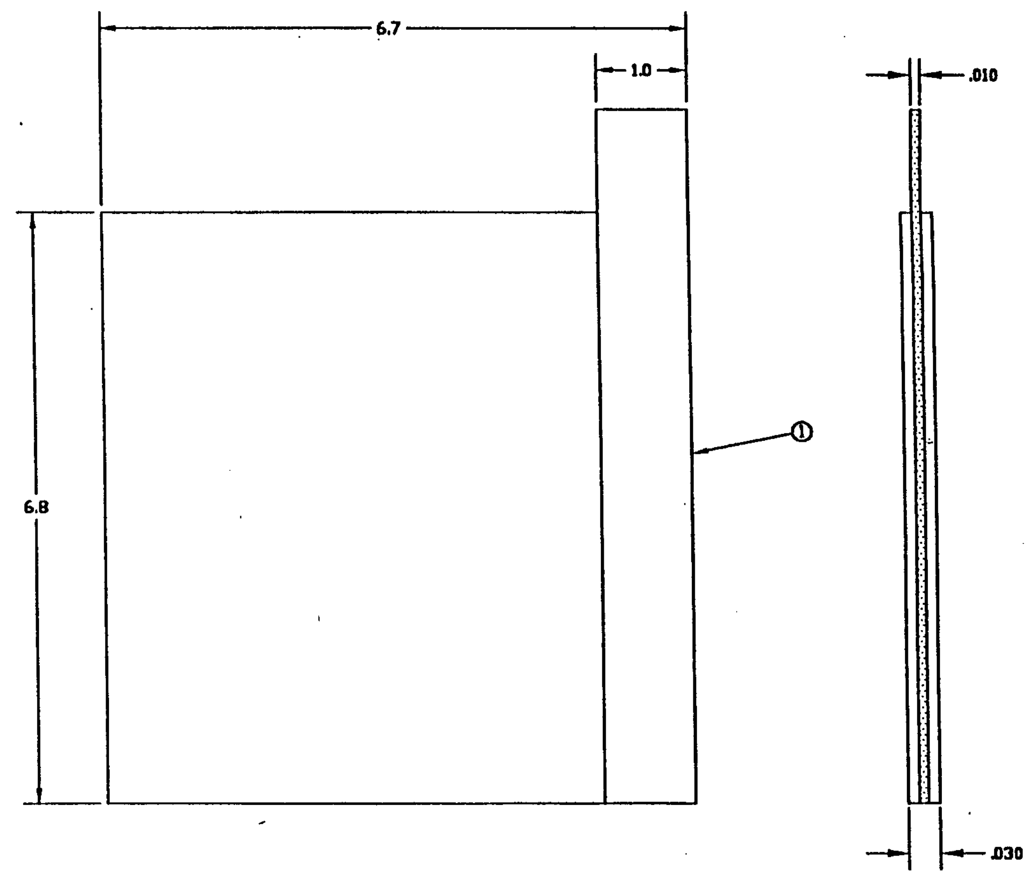
SCALE 1/1 | SHEET 1 OF 1

CONTROL A

PART NO.
72007242-101

NOTES:

1. MATERIAL: LITHIUM COBALT DIOXIDE
2. CATHODE SURFACE AREA PER SIDE IS 170 sq. cm.
3. TWO CATHODE PADS PER CATHODE.
4. TOLERANCE:
   .X ±.020
   .XX ±.010
   .XXX ±.005
5. ALL DIMENSIONS ARE IN INCHES.
6. PER PROCESS PROCEDURE 7200711-1.



72007242 | SH 1 | REV –

QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	REMARKS	ITEM NO.
1	72007009	CATHODE GRID ASSEMBLY		1

PARTS LIST

ALLIANT TECHSYSTEMS — POWER SOURCES CENTER

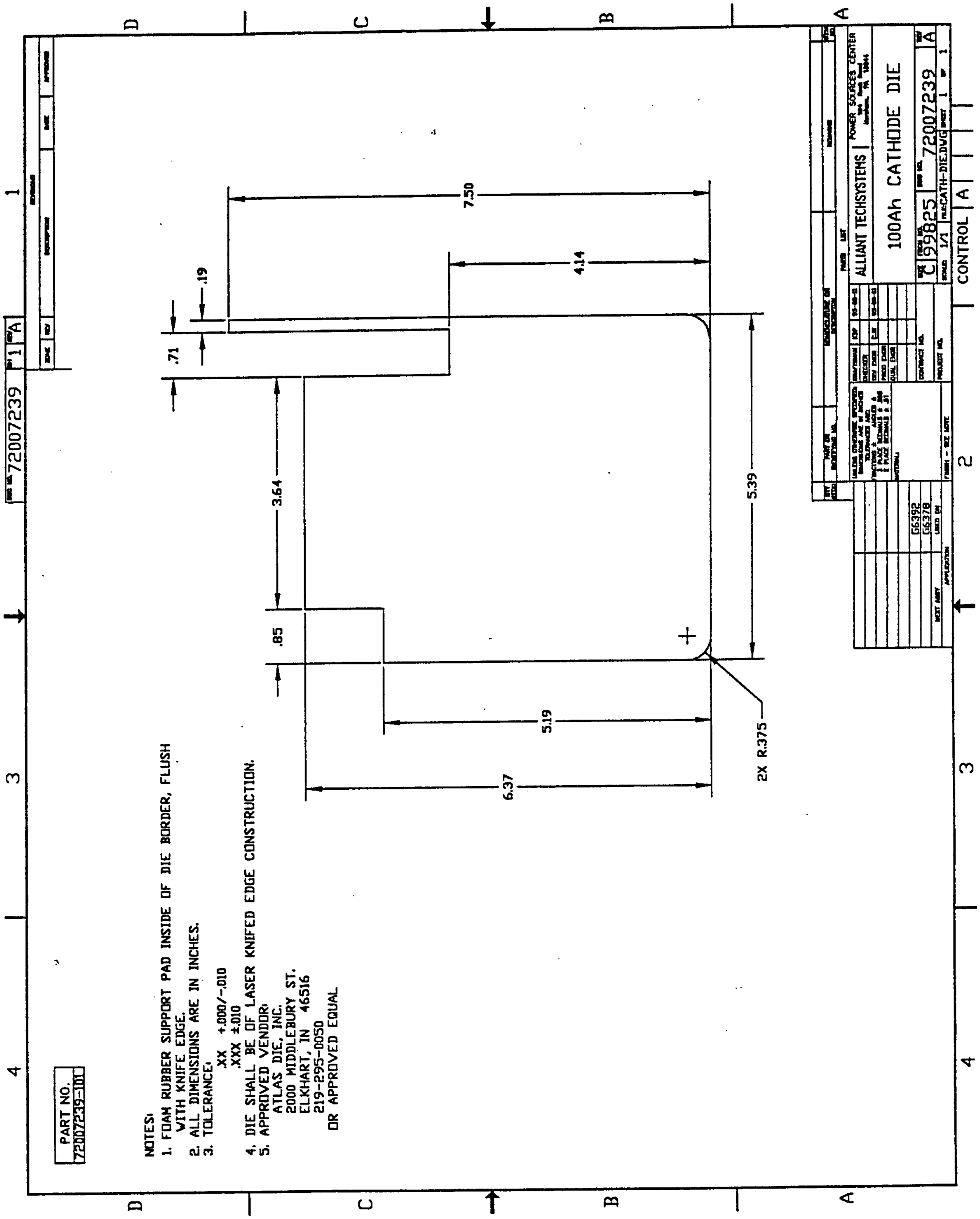
100 AH CATHODE PAD SUBASSEMBLY

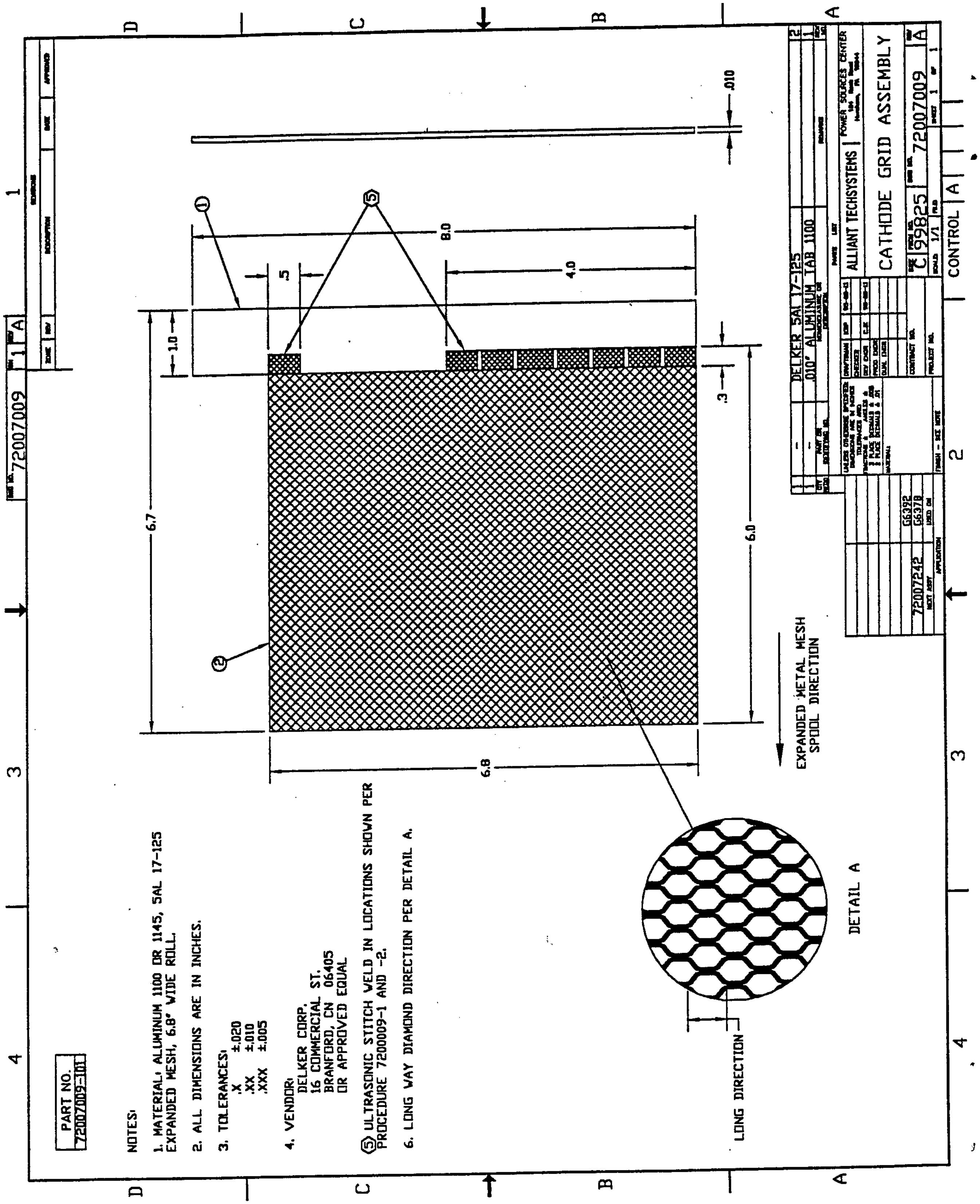
SIZE C | FSCM NO. 99825 | DWG NO. 72007242 | REV –

SCALE 1/1 | SHEET 1 OF 1

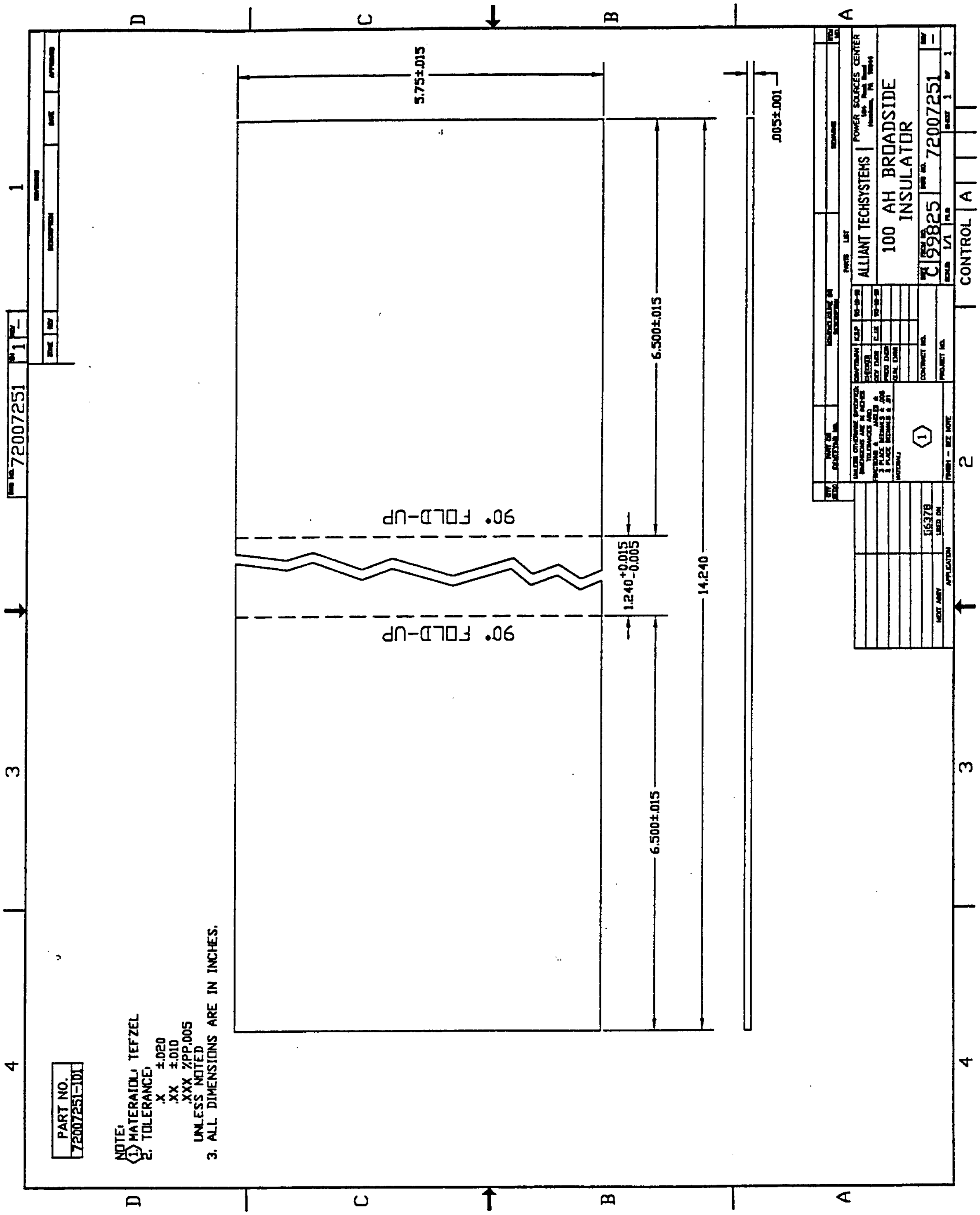
NEXT ASSY 72007011 | USED ON G6378

CONTROL A

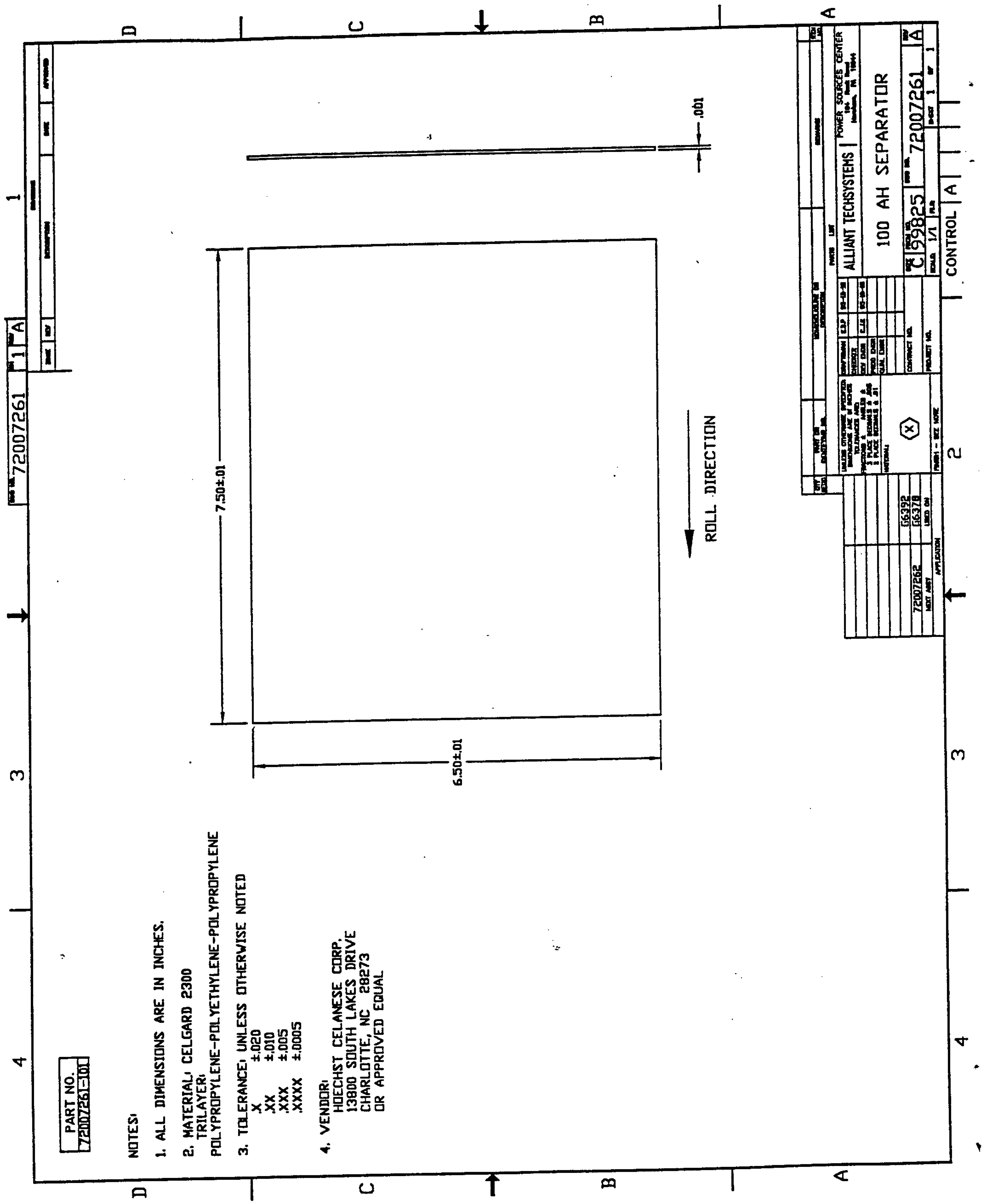

DWG NO. 72007239
SH 1 REV A
7.50
4.14
.19
.71
3.64
5.39
.85
5.19
6.37
2X R.375
NOTES:
1. FOAM RUBBER SUPPORT PAD INSIDE OF DIE BORDER, FLUSH WITH KNIFE EDGE.
2. ALL DIMENSIONS ARE IN INCHES.
3. TOLERANCE:
.XX +.000/-.010
.XXX ±.010
4. DIE SHALL BE OF LASER KNIFED EDGE CONSTRUCTION.
5. APPROVED VENDOR:
ATLAS DIE, INC.
2000 MIDDLEBURY ST.
ELKHART, IN 46516
219-295-0050
OR APPROVED EQUAL
PART NO.
72007239-101
ALLIANT TECHSYSTEMS
POWER SOURCES CENTER
100Ah CATHODE DIE
C 99825 72007239 A
SCALE 1/1
CATH-DIE.DWG
SHEET 1 OF 1
G6392
G6378
CONTROL A



PART NO.
72007009-101
NOTES:
1. MATERIAL: ALUMINUM 1100 OR 1145, 5AL 17-125 EXPANDED MESH, 6.8" WIDE ROLL.
2. ALL DIMENSIONS ARE IN INCHES.
3. TOLERANCES:
.X ±.020
.XX ±.010
.XXX ±.005
4. VENDOR:
DELKER CORP.
16 COMMERCIAL ST.
BRANFORD, CN 06405
OR APPROVED EQUAL
5 ULTRASONIC STITCH WELD IN LOCATIONS SHOWN PER PROCEDURE 7200009-1 AND -2.
6. LONG WAY DIAMOND DIRECTION PER DETAIL A.
LONG DIRECTION
DETAIL A
EXPANDED METAL MESH
SPOOL DIRECTION
6.7
1.0
.5
8.0
4.0
.010
.3
6.0
6.8
72007009
1
A
DELKER 5AL 17-125
.010" ALUMINUM TAB 1100
ALLIANT TECHSYSTEMS
POWER SOURCES CENTER
CATHODE GRID ASSEMBLY
C
99825
72007009
A
CONTROL
A
72007242
G6292
G6378



100 AH BROADSIDE
INSULATOR
72007251
ALLIANT TECHSYSTEMS
POWER SOURCES CENTER
59825
CONTROL
90° FOLD-UP
90° FOLD-UP
5.75±.015
.005±.001
6.500±.015
6.500±.015
14.240
PART NO.
72007251-101
NOTE:
1. MATERAIDL: TEFZEL
2. TOLERANCE:
.X ±.020
.XX ±.010
UNLESS NOTED
3. ALL DIMENSIONS ARE IN INCHES.


72007261
1
A
D
C
B
A
1
2
3
4
.001
7.50±.01
6.50±.01
ROLL DIRECTION
ALLIANT TECHSYSTEMS
POWER SOURCES CENTER
100 AH SEPARATOR
C
99825
72007261
A
1/1
CONTROL
A
72007262
G6392
G6378
PART NO.
72007261-101
NOTES:
1. ALL DIMENSIONS ARE IN INCHES.
2. MATERIAL: CELGARD 2300
TRILAYER:
POLYPROPYLENE-POLYETHYLENE-POLYPROPYLENE
3. TOLERANCE: UNLESS OTHERWISE NOTED
.X ±.020
.XX ±.010
.XXX ±.005
.XXXX ±.0005
4. VENDOR:
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OR APPROVED EQUAL

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